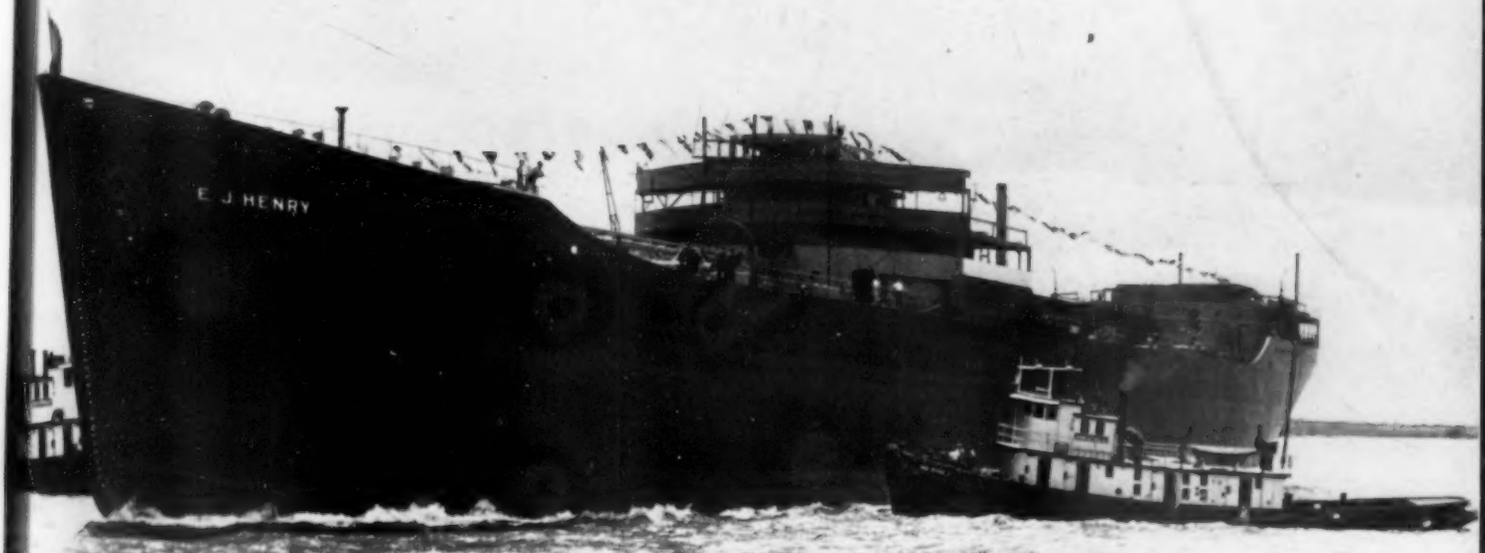
The Welding Journal

SEP 1 0 1939



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The American Welding Society Journal

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Published for the Advancement of the Science and Art of Welding

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Tugs maneuver the 18,100-ton S.S. E. J. Henry toward the dock after her launching at the Sun Shipyards, Chester, Pa., on July 29th.

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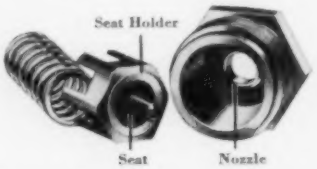
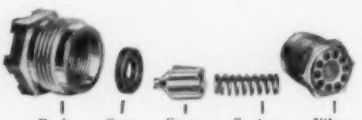


Second-stage Valve — the "heart" of the regulator—is built for precise gas delivery in large or small volume. It closes *with* the pressure. Chromium-plated nozzle will not corrode, won't cut seat.



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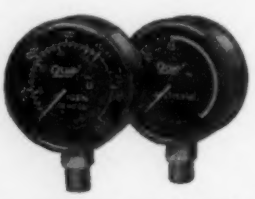

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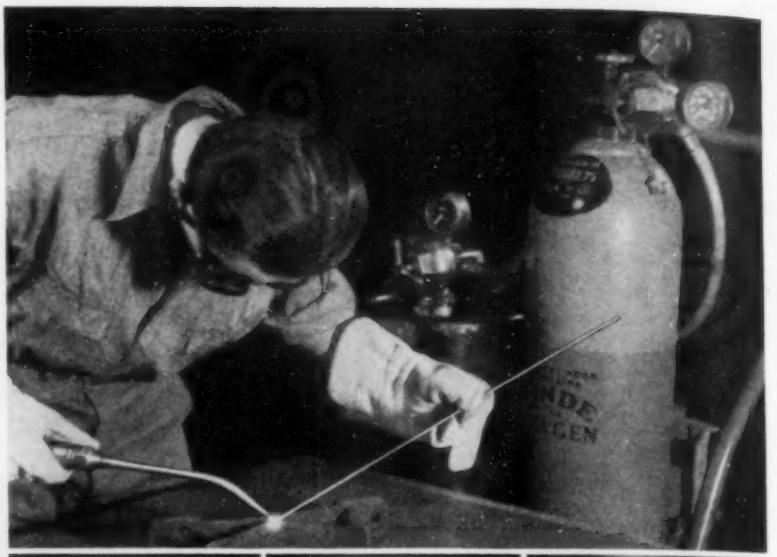

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Welding Journal

VOLUME 18, No. 9 SEPTEMBER 1939

FLAME HARDENING ROLLERS AND Roller Paths

By ROY L. SPAULDING*

THE requirements of modern crane design include roller path loading, which would be entirely impractical with ordinary materials and treatments. However, after flame hardening, these paths will withstand greatly increased loads and give a longer service life. The particular adaptability of flame hardening as a means of treating these parts is readily understood from the inherent characteristics of the process.

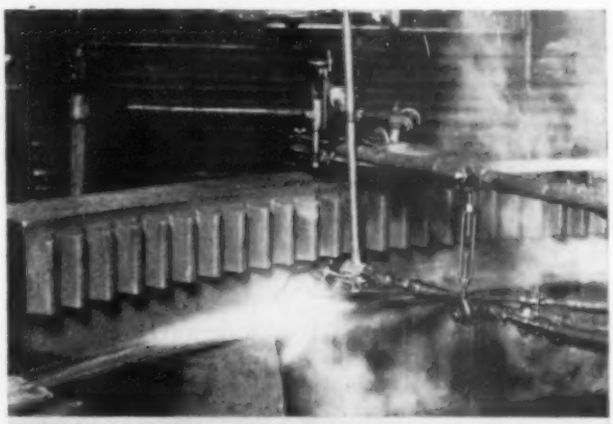
In the first place, flame hardening is a localized treatment which may be progressively done on parts too large to be treated in any other way. The hardening operation does not damage the surface or cause excessive distortion, so it may be performed after machining, which eliminates the expense of machining hard material. In addition to the characteristic of imparting a hard surface to resist wear while leaving the core strong and ductile, the process will automatically produce a transition zone in hypoeutectoid steel which leaves no definite line of demarcation between the hardened surface and the unhardened core. This characteristic is said to be responsible for the lack of tendency for the hardened surface to crack or peel away from the core.

The value of flame hardening for this application also rests on the hardness values which may be obtained with ordinary materials. For instance, a plain 0.35% carbon steel one inch round, when heated to the upper critical in a furnace and quenched in cold brine, will give a Brinell hardness of about 400. However, this same analysis may be flame hardened to 500 Brinell. The higher hardness of the flame hardened specimen is attributed to the extremely rapid quench produced simultaneously by the cold water spray and the chilling effect of the cold metal below the heated area. It should be emphasized that flame hardening imparts a hard wear resistant surface for service which requires this condition. Where service conditions also impose high fiber stresses, these must be met with stronger core material in addition to a hard surface.

A discussion of some of the methods used to obtain the desirable properties of a flame hardened surface on such parts as crane rollers and roller paths is given in the following paragraphs. Although the progressive method is not the only means of flame hardening, it is the one best adapted for use on these parts. Where the width of the path being hardened is not too great, 3 inches to 5 inches, it is generally better to use a torch with a tip wide enough to cover the whole width with one pass. The torch with the single row of quenching holes using a cold water quench has been found most satisfactory for treating plain carbon steels in the range 0.35% to 0.55% carbon or alloy steels of similar hardenability.

Detail methods for the flame hardening operation are always worked out to suit the needs of the particular job, using the tools and materials available. However, all methods are based on the principle of heating a hardenable steel surface by means of an oxyacetylene flame with such rapidity that the desired depth is brought above the critical temperature range while the main portion of the body remains essentially unheated, and immediately following the heating cycle by a suitable quench which develops the desired hardness. To suc-

Fig. 1—Hardening a Large Revolving Crane Roller Path with the Torch Tilted for Clearance and Proper Heat Distribution



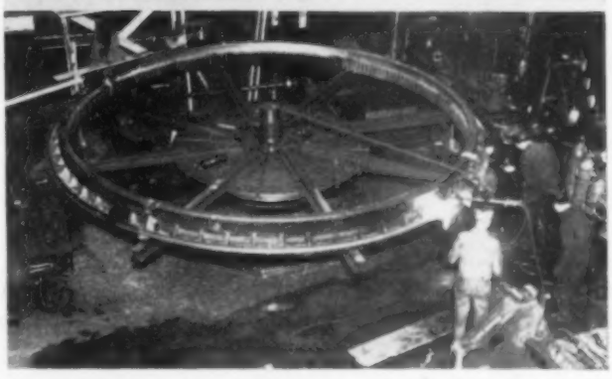


Fig. 2—Hardening a Large Revolving Crane Roller Path with Driving Monitor Traveling Directly Back of and on the Same Path That Is Being Hardened

* American Hoist and Derrick Company, St. Paul, Minn.

Fig. 3—Hardening a Roller. Note That the Man on the Left Is Applying the Diagonal Finishing Shield

Fig. 4—The Fixture for Hardening Rollers. Note That the Torch Is Swung Out of the Way While Placing a Fresh Roller Into Position

cessfully apply this principle, a number of variables must be coordinated and controlled. These include gas pressures and purity; height, angle and rate of travel of torch; temperature, quantity and location of quenching medium. Of course, the ideal set-up would have all these variables constant for the duration of a run. As this is seldom possible, small compensating adjustments are necessary to give a uniform job. Gas pressures are readily controlled by using good two-stage regulators and by allowing the torch valves to be wide open during operation. Gas purity or composition may be held nearly constant throughout a run by connecting a sufficient number of tanks to one manifold so that the rate of discharge from each tank will be less than the maximum recommended by the suppliers. The height and angle of the torch is a function of the stability of the driving monitor, as the torch may be clamped securely to this unit. Rate of travel may be easily controlled with a good driving monitor. The control of temperature, quantity and location of the quenching medium is usually not difficult when a well designed tip is used with a water system in which the pressure is fairly constant.

During preliminary trials, much difficulty was experienced in obtaining the required stability of the driving monitor. As the monitor travelled, its relative height would change, bringing the torch closer to or farther away from the work, resulting in uneven heating and uneven hardening. To eliminate this variation, three methods were worked out and successfully applied. For large roller paths, the driving monitor is operated on a path which is machined parallel to the path being hardened, as shown in Fig. 1, or *on* the path which is being hardened, as shown in Fig. 2. For hardening rollers, the torch height is held constant by rotating the roller on its true axis while the torch is held stationary, as shown in Figs. 3 and 4.

When any of these set-ups is in operation for a long time, the torch and driving mechanism must be protected from the heat of the torch flame. It was found satisfactory to use sheet steel shields in combination with a rapidly moving stream of air to dissipate the heat from the flame. This stream of air is induced by connecting to an air line a $^1/_2$-inch pipe with a row of $^1/_{16}$-inch holes spaced $^3/_{16}$ of an inch apart. Although the air blast was not used in the set-up shown in Fig. 1, it is one of the most valuable devices for this type or work. In Fig. 2, the pipe for the air supply is shown directly back of the torch head, with its connecting hose going back over the radius bar and driving monitor.

The method shown in Fig. 2 utilizes the same set-up which was used in machining the roller path, thus eliminating the time which would be used to level the path and locate its center. A crank is attached to the driving motor on the machine so that the path may be rotated periodically to keep the hardening apparatus in approximately the same location while the entire circumference of the roller path is being hardened. This arrangement eliminates the necessity of running the hose to the center of rotation and out to the torch along the radius bar. When the machine is being used for other work, a similar set-up is made on the floor by running the hoses underneath to a temporary king pin and out along the radius bar. With this set-up, the torch is driven completely around the circle.

In addition to showing a convenient means of controlling torch height, Fig. 1 illustrates two other principles for flame hardening surfaces. Careful examination of the figure will disclose that the torch head is sloping back at quite an angle. This was necessary because of limited head room. It has been found through considerable experience that this procedure when carefully applied will give perfectly satisfactory results. It has further been found that the angle at which the flame strikes the surface is not critical and may be varied as much as 30° from the vertical. How-

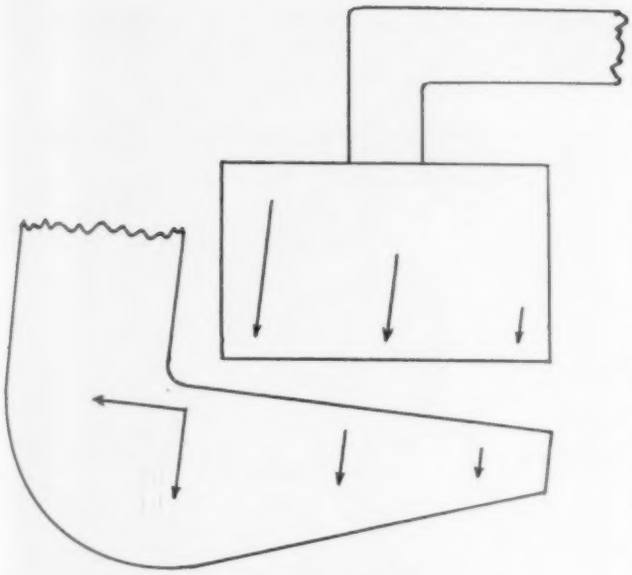


Fig. 5—Schematic Diagram Showing Relation of Mass to Necessary Heat Input and Means of Regulating Heat Input by Tilting the Torch

ever, the tip should be sloped about 3° ahead of vertical to obtain the best flame and quench stability and gas economy. This would give a slope of 23 degrees to a quenching stream which is built 20° from the line of the flame holes in the tip.

The second principle brought out by this application is the effect of mass on the necessary distribution of heat input. A section of the roller path taken at right angles to the direction of travel is shown in Fig. 5.

As represented by the length of arrows in the roller path (below), the dispersion of heat will be greater at the left where the mass is greater and where the heat can travel in more than one direction. To compensate for this condition and get a more uniform temperature across the surface being hardened, the heat input, represented by arrows in the torch (above), is made greater at the left where the dispersion is greater by tilting the torch, bringing the left side closer to the work. The amount of tilt is intentionally exaggerated in the sketch. In the set-up illustrated in Fig. 1, the turnbuckle which adjusts this tilt is seen attached to the torch handle on one end and the radius bar on the other.

Besides controlling the many variables during operation, there is the added problem of overlap when flame hardening continuous circular paths. After travelling completely around a circular path with a flame hardening torch, there will be a portion of the previously hardened metal just ahead of the torch whose temperature is between the critical necessary for hardening and the ambient of the surrounding air. The higher ranges of this temperature will be sufficient to partially remove the hardness of the previously hardened area; yet, being below the critical, there will be no hardness developed by quenching. As it is impossible to eliminate this condition, methods are employed to overcome any ill effects which it might cause.

By increasing the temperature gradient, the width of the softened area may be narrowed to around $^1/_{16}$ inch. A good means of getting this steep temperature gradient at the end of a circular path is to shield some of the previously hardened area with a hollow copper strip which is flooded internally with water while the torch is allowed to pass over it. The edge which first comes under the torch should be a good fit with the hardened surface to prevent the flames from licking under the shield, greatly increasing the width of the partially heated band.

Although a $^1/_{16}$-inch wide band with hardness somewhat below that of the surrounding surface is ordinarily not detrimental, another step is taken to improve the condition. The leading edge of the copper finishing strip mentioned in the previous paragraph is made at an angle of 45° with the line of contact of the rollers. In this way every position of the roller will be supported by a preponderance of hardened area.

Figure 3 shows the application of this diagonal finishing strip to the finish on an 8-inch diameter roller with a face $3^1/_4$ inches wide. This same set-up with the torch swung out of position for removing the hardened roller and placing a soft one in position is shown in Fig. 4.

In conclusion, some mention of actual service results should be made. Of all the flame hardened rollers and roller paths which have been put into service during the past two years, there has been no indication of any type of failure. A recent inspection of a roller path that has seen constant service since its installation two years ago disclosed no appreciable wear.

ACKNOWLEDGMENT

The writer is indebted to Mr. H. L. Campbell of the American Hoist and Derrick Company and to Mr. Robert Flood of The Linde Air Products Company for their assistance in the preparation of this paper.

A FENDER REPAIR

By GEORGE KOTCHER*

OXYACETYLENE WELDING, HEATING AND SOLDERING ARE USED TO REPAIR A CRUSHED FENDER

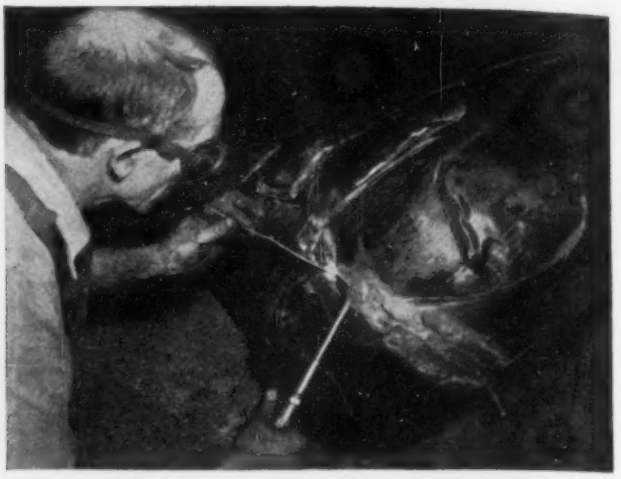
WHEN it comes to mending rips in crushed and torn fenders, the oxyacetylene flame is often called upon to perform the miraculous. This is well illustrated by the accompanying series of photographs. Normally, this fender would be considered to be beyond repair, and would be consigned to the junk heap without much further thought. But when the owner of the car learned that a new fender could not be obtained in less than two weeks, he decided to have it welded. He was especially pleased with the results and found that the repair cost was still less than the cost of a new fender.

After the fender had been rough-shaped with a hammer and dolly block, the larger of the tears was welded in

* The Linde Air Products Co.

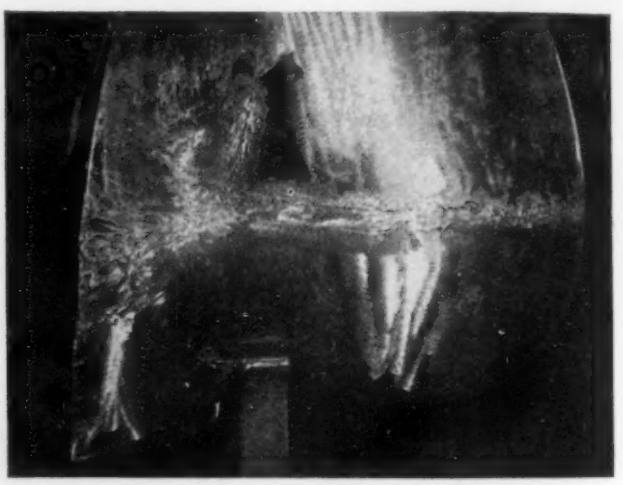
successive stages. A tack-weld was made 3 in. from the edge, this section welded, then the fender was further hammered and shaped so that another 3-in. section could be similarly tack-welded and welded. This procedure was followed until the crack was completed. Drawn iron welding rod was used with a neutral flame.

1 This Is a Tough Job for Any Fender Repair Shop. The Large Crack is 3 Ft. Long and There Are a Dozen Smaller Cracks. The Fender Is Partially Hammered into Shape



2 Successive Operations of Hammering and Welding Transform the Crumpled Mass of Metal Into Something More Nearly Recognizable. The Large Crack Is Almost Completed

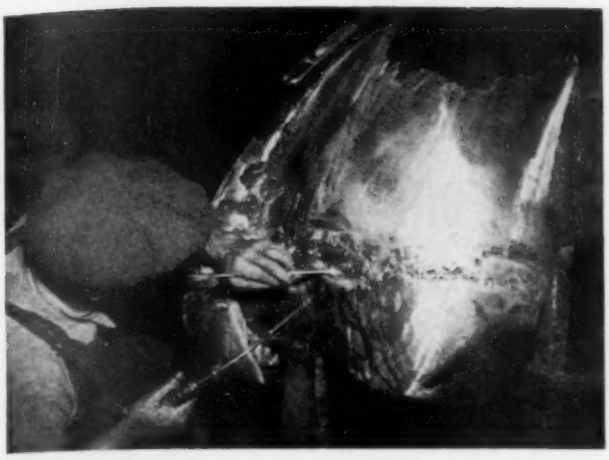
3 A High Spot Is Removed. The Area Is Heated to a Bright Red Temperature, Then Hammered With a Wooden Mallet While the Dolly Block Is Held Against the Underside



4 This Close-Up Gives a Good Idea of the Extent of the Welding Repair. Weld Metal Has Been Hammered and Depressed for Subsequent "Wiping" Operations

5 The Fender Is Finish-Shaped by Hammering. The Hammer Marks Are Then Removed with a "Slapper," and Weld Areas Are Cleaned with a Portable Grinder

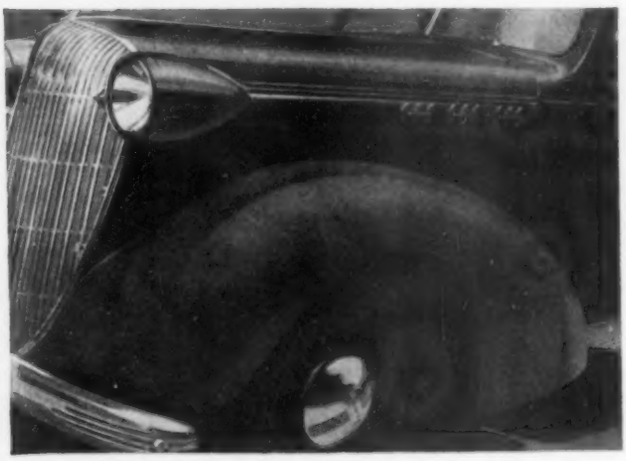
6 The Metal Is Heated Slightly and Cleaned with Acid, Then It Is Tinned with a Soft Body Solder and the Tinned Areas Gone Over with a Wire Brush



7 Here the Depressed Weld Areas Are Being Filled in with Body Solder. A Soft, Excess Acetylene Flame as Slender as a Pencil, Is Used for This Operation

8 The Rough Deposit of Solder Is Reheated and Smoothed or "Wiped" With a Wiping Paddle. All Welds in the Fender Are Treated in This Fashion

9 Finally, All Soldered Areas Are Smoothed with a Portable Grinder. The Fender Is Then Attached to the Car and Is Ready for Subsequent Painting and Polishing Operations



10 It's Hard to Believe That This Is the Same Fender as That Shown in the First Illustration. Only an Expert Could Tell That It Is Not a New One

GAS WELDING OF OIL WELL CASING*

By G. R. MILTON†

FOR a number of years, we have been welding oil well casing. We first used this method on account of lack of sufficient hole clearance for the couplings on the casing. The oxyacetylene method of running casing was not adopted as a general practice by our company, except in cases of necessity such as caused the first experiment, until some three or four years ago, due to the slow methods of oxyacetylene welding known prior to that time.

In 1934 and 1935, our company had several hundred miles of surplus pipe which they desired to use for oil well casing, and which could not be converted into screw pipe, for various reasons. Experiments were made as to the best method that could be adopted for utilizing this pipe, and we found that oxyacetylene welding, due to its speed and quality from new innovations developed in recent years, was the most logical method. This was due to the fact that the pipe could be used by simple field preparations; other methods required special joints, necessitating mill-prepared pipe, which would have rendered impossible our use of this pipe.

In order to speed up production, a number of water-quench tests were made, with satisfactory results, but in actual operation it was found that the human element would not allow us to continue this practice.

Oxyacetylene welding having been decided upon as the best method for utilizing this pipe, our next problem was the engagement of competent welders. As the pipe would of course be run vertically, the weld would be entirely different from that used by pipe-line welders, who might be entirely capable of making a roll weld on a pipe line,

* Presented at the 39th Annual Convention of the International Acetylene Association, Houston, Texas, March 8, 9, and 10, 1939.

† Shop Foreman, Sinclair Prairie Oil Company, Arp, Texas.

but who could not be any better welder than a student in this different type of welding. Rigid tests were therefore established for all welders hired for this work, and after a period of training, those unable to qualify were rejected. All qualified welders were tested periodically after their training period; the success of this method was amply proved by tests of coupons cut from the pipe, in which we found that about one out of two thousand specimens failed adjacent to the weld, due to lack of penetration, which in itself was not due to the method or material, but to the human element.

For greater speed in the actual running of this pipe, it was converted into forty-foot lengths, which reduced by one-half the number of field welds necessary at the well. A hydrostatic test being one of the requirements of the Railroad Commission, we subjected every joint to a test pressure of eight hundred to one thousand pounds, and in 16,000 joints, each of which had been welded, we found four rejections due to pinholes in the weld.

Very little instruction was necessary to enable the drilling crew to handle the welded casing as expeditiously as ordinary screw casing. The joint was lowered in the hole and the slips set to leave approximately five feet of pipe above the derrick floor; the next joint was picked up and set on top of this lower joint, being held in place by specially prepared clamps which had spacers to keep the joints the proper distance apart. Two welders then tacked the pipe while it was held in the clamps, the latter were removed and the welders immediately commenced welding, each one completing half the weld and making the tie-in where the other had started. A simple device was installed in the derrick which held the top of the joint in a straight line, and stationary.

A cooling time of one minute after completing the weld was allowed on the first third of the string; the next third was allowed to cool two minutes, and the remainder cooled for three minutes, before being run into the hole.

After the pipe was set and cemented, and allowed to stand in accordance with Railroad Commission rules, a hydrostatic test of six hundred pounds per square inch was made, with the pipe subjected to this pressure for a period of twelve hours.

The utilization of this surplus pipe, at as small expense as possible, with a consequent saving in capital expenditures, being the primary reason for our adoption of the welded method of oil well casing, a study of the costs revealed that we had been justified in adopting this method. Direct costs—that is, labor and material—on $6^{5}/_{8}$-in. O.D. pipe, averaged approximately $75.00 per oil well, the wells having an average depth of thirty-four to thirty-eight hundred feet. This per-well cost is subject to variation, due to circumstances beyond the control of the welding department, just as screw casing might cost more in one well than in another due to circumstances over which the casing crew have no control.

The bulk of the pipe used by us for casing by the oxyacetylene welding method was $6^{5}/_{8}$-in. O.D., but 7-in. O.D. and $8^{5}/_{8}$-in. O.D. pipe was also run by this same method, at a slightly higher cost, due to the weld on the larger pipe requiring more time and material. Approximately two hundred oil wells were cased by this method in the East Texas field by our company.

During recent months, the same method has been used by our company in the Kansas field. Several strings of 5-in. O.D. casing have been run in that field, and new developments have expedited this process to a considerable degree. The multi-flame tip, which allows the weld to be made in a shorter time, and a copper quenching clamp, which allows the weld to be water-cooled without the risk attendant as before, have greatly shortened the running time necessary in this method, and naturally have also reduced the costs to some extent.

Discussion of G. R. Milton's Paper on Oxyacetylene Welding of Oil Well Casings*

By F. C. HUTCHISON†

MR. MILTON and his company should be congratulated on the real contribution that they have made in the application of welding to oil well casings. Their East Texas operation in which they utilized, for economic reason, line pipe for their well strings, was probably the first wholesale application that was made of casing welding; at least in the mid-continent area. Their experience with and belief in the oxyacetylene process, as it was then developed, led them to feel that they would have more success with this method than with any other available practice.

It should be emphasized that the pipe metal was Grade B, which is sufficiently low in carbon content and ultimate strength that they felt reasonably confident of attaining practically 100% joint efficiency.

During the training of their operators some investigation was carried on to tell whether they were safe in water quenching the welds. This study led them to conclude that a delayed quenching was necessary. A mention is made that this quenching procedure was later abandoned due to "human element." This "human element" had nothing to do with the welding operation but simply was based on the fact that they could not adequately supervise the quenching routine, with the result that in a good many instances the water streams were directed immediately upon this joint at the hottest part of the weld the instant the torches were turned off. In other words, it would be emphasized that the theory on delayed quenching was developed but the practice not adopted because the delay could not be made uniform.

Casing pipe today is of very high physical strength; the high strength being obtained by use of a high percentage of carbon or by the alloying of certain elements such as copper, manganese, etc. These higher carbon and low alloy metals present two problems: (1) weldability, as the carbon is higher than what has been considered in the past as an acceptable maximum value, and (2) accelerating the cooling down of the completed weld without seriously and injuriously affecting the structure and properties of both the weld metal and the adjacent base metal.

To date, welding of casing is still more or less in the experimental stage. Welding would be adopted more extensively if certain phases, both practical and metallurgical in nature, were solved and information made available concerning them. With this in view, our company has made an extensive investigation of oxyacetylene welding of casing, covering not only the practical, economic aspects, but a metallurgical study of the whole problem as related to various grades of casing. This work has included the development of multiple flame tips for speeding the welding, experimentation in accelerating the cooling of the weld to expedite lowering the casing

* Presented at the 39th Annual Convention of the International Acetylene Association, Houston, Texas, March 8, 9 and 10, 1939.
† The Linde Air Products Company, Kansas City, Mo.

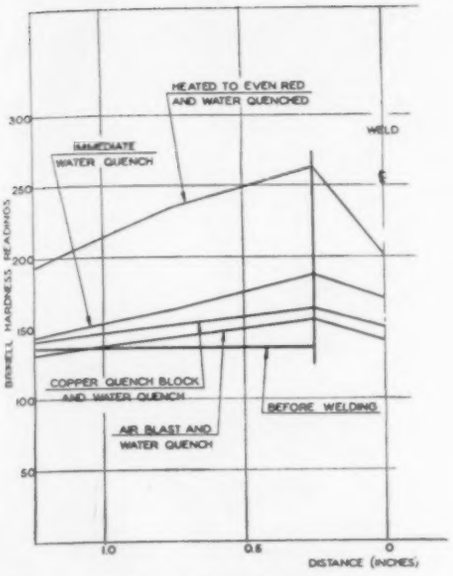


Fig. 1—Casing Welding
Transverse Sections
Average Hardness of Weld and Casing
X-API Grade B Casing

after welding, and the development of quench procedures that give the requisite physical properties of the joint without adversely affecting, metallographically, either the weld or the adjacent base metal.

CASING METALS INVESTIGATED

Three sizes of casing were investigated. These were 5 in. and $5^1/_2$ in. O.D. by 0.304 inch wall thickness and 7 in. O.D. by 0.362 wall thickness. The chemical analysis for carbon and manganese is given in Table 1. Two analyses were made of each of the various grades of casing used in the investigation.

Table 1—Chemical Analysis of Casing

Make and Type of Casing	Manganese, Per Cent	Carbon, Per Cent	Copper, Per Cent
X*—A. P. I. Grade B	0.56	0.24	.....
X —A. P. I. Grade B	0.59	0.27	.....
X —A. P. I. Grade C	0.87	0.41	.....
X —A. P. I. Grade C	0.89	0.35	.....
Y —A. P. I. Grade C	1.27	0.49	.....
Y —A. P. I. Grade C	1.00	0.44	.....
Z —Low Alloy Grade C	1.03	0.23	0.45–0.70
Z —Low Alloy Grade C	1.19	0.30†	0.45–0.70

* Prefix indicates casing supplied by different pipe mills.
† Attention is called to the fact that the carbon content of this specimen exceeds the specification figure of 0.25 per cent.

Table 2—A. P. I. Specifications for Physical Properties of Casing

Type Casing	Yield Point, Lb. per Sq. In.	Min. Tens. Strength, Lb. per Sq. In.
A. P. I. Grade B	35,000	60,000*
A. P. I. Grade C	45,000	75,000
Low Alloy Grade C	45,000	75,000

* Because of the necessity for placing carbon limits on line pipe for welding, the physical properties of Grade B pipe are slightly lower than the Grade B material in A. P. I. Std. No. 5-A.

EFFECT IMMEDIATELY FOLLOWING QUENCHING

In order to determine accurately what hardness would be developed in different grades of casing under various quenching conditions, sections of unwelded pipe were furnace heated to different temperatures and immediately water quenched. Table 3 gives the results of this study.

The average hardness curves for each quench method investigated on various types of quenching are given in the accompanying curves. These curves give the Brinell Hardness in the weld and adjacent pipe material, and for comparison, the original hardness of the base metal before welding.

VARIOUS METHODS OF QUENCHING INVESTIGATED

Numerous methods of cooling the weld rapidly were tried to determine their effects on the physical properties and the micro-structure of the joint. The first method of quenching was a direct water quench on the weld immediately following completion of the joint. Other methods of accelerating the cooling of the weld were investigated. These included, in addition to water quench, a steam quench, air quench and a copper block quench, which are explained individually as follows:

Water Quench: Two $^3/_4$-inch hose were used to spray water on opposite sides of the weld at the hottest points until the metal was cooled below 200° F.

Steam Quench: Two jets of steam were directed on the weld at the hottest portions, until the metal was cooled below 500° F.

Air Quench: Two $^3/_4$-inch hose were used to direct air streams on the welds at the hottest portions until the metal reached black heat. A water quench was then used to bring the metal down to 200° F.

Copper Quench Block: The block,* which will be described later, was clamped around the hot weld as soon as possible after completion of the joint. Water was then played on the lower pipe to draw the heat from the weld.

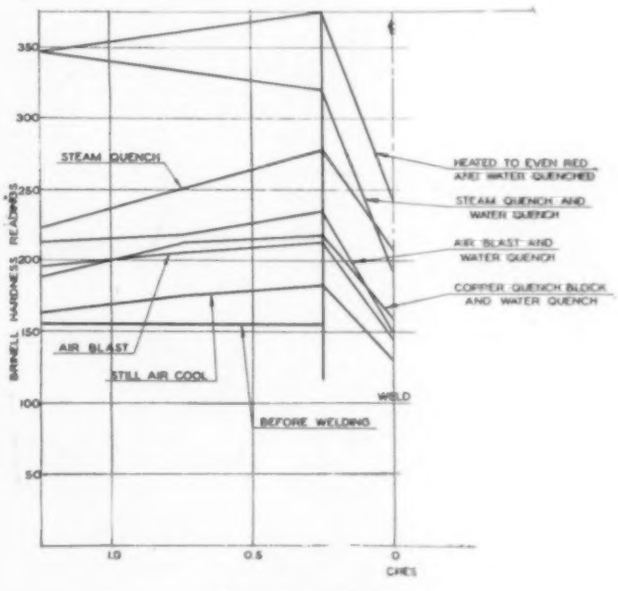


Fig. 2—Casing Welding
Transverse Sections
Average Hardness of Weld and Casing
X-API Grade C Casing

* Patent applied for.

When the weld had cooled to a black heat the clamp was removed and the weld cooled to 200° F. by water jets.

Samples for testing were taken from each weld, at least one specimen being taken from the finish zones which were the hottest points on completion of welding. These specimens were given a metallographic inspection and tested for physical properties. All hardness readings were made with a Rockwell Superficial Hardness Testing Machine and converted to Brinell Hardness by the Rockwell Conversion Table. The hardness in the weld and in the adjacent heat-affected bare metal are shown on the various curves.

It is to be noted that the highest hardness occurs not in the weld but in the base metal immediately adjacent to the weld. It is also to be noted that the hardness of both the weld metal and the heat-affected base metal is not very much higher than the original base metal when the copper quench block was used.

FULL SIZE TENSILE TESTS

In order to determine the physical strength of full size joints subject to direct quenching treatment, tensile tests of full size pipe joints were made of Grade B pipe. The pipe was $5^1/_2$ inches O.D. having a wall thickness of 0.265. One of the joints was immediately water quenched upon completion of welding, and the second one was given a treatment to accelerate the cooling by using a copper quench block. In both cases the full strength of the pipe was developed; failure occurring about a foot and a half from the weld. The yield was about 40,000 lb. per sq. in. and the ultimate tensile strength 60,000 and 61,000 lb. per sq. in. for the two joints tested.

A few other preliminary tests were made on full joint specifications, which were cooled by the use of a copper quench block to protect the weld upon being water quenched. These preliminary tests did not develop extremely high strength in Grade C casing inasmuch as the strength of the metals are not higher than 90,000 or 95,000 lb. per sq. in. The joint efficiencies, however, were better than 95% of the specified minimum tensile strength of the metal. These efficiencies are, therefore, much higher than obtainable with screwed, coupled casings used to date.

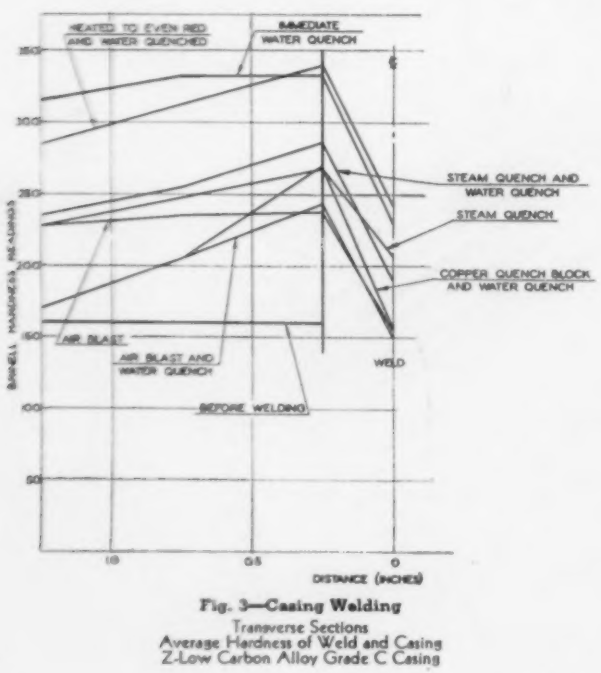


Fig. 3—Casing Welding
Transverse Sections
Average Hardness of Weld and Casing
Z-Low Carbon Alloy Grade C Casing

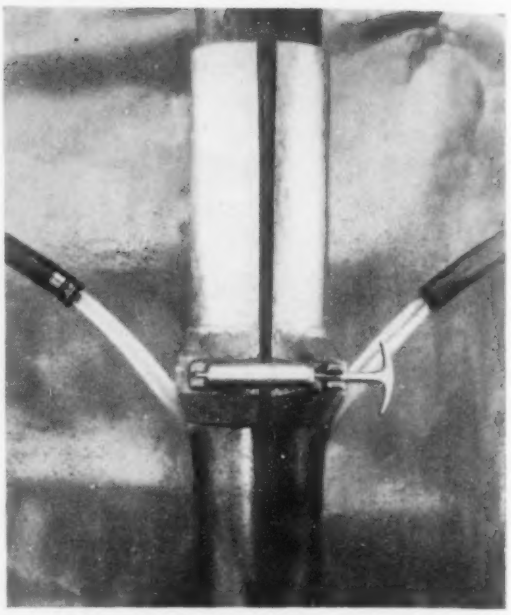


Fig. 4—Correct Application of Copper Block Quench Method
Note: Stream Directed on Pipe Immediately Below Hottest Points of Weld

COPPER QUENCH BLOCK*

The quenching procedure found to be extremely satisfactory for all types of casing used, including A. P. I. Grade C and low alloy Grade C, was to employ a water quench with a copper quench block protecting the weld. The recommended quench block is shown in Fig. 4 and consists of a hinged heavy copper body about 4 in. wide, grooved at the center to fit over the weld, protecting it for 2 in. on each side. A skirt (above) 12 in. high protects the weld from any splashing of water that might run down over the top of the block and onto the hot area.

On completion of the weld, the block is fitted into position by means of two hinged halves held in position by a clamp. The assembly is designed to fit snugly around the casing at 1000° F. It is necessary to have a quench block designed for each different size of casing.

The quench block is assembled with the hinge and clamp located between the two finish points so that the middle of each half of the block thoroughly protects the hot finishing points.

Although the copper quench block conducts heat away from the weld, the greatest amount of heat is lost by conduction through the casing wall from the weld to the water-cooled area immediately below the block. The block is kept on the weld for a length of time specified for the different wall thicknesses of casing, approximately one to one and one-half minutes. On removal of the block, the water can be played directly on the weld for 5 to 10 seconds.

It was found, in general, that with the exception of Grade B pipe, the immediate water quench and steam quench were entirely too drastic and unsatisfactory for the weld, and particularly the adjacent pipe material. The hardness resulting from these quench treatments was too high, indicating brittleness in the base material adjacent to the weld.

The only entirely satisfactory quenching procedures were found to be the air quench and the copper block quench with water.

* Patent applied for.

Table 3—Hardness of Each Grade of Casing Water Quenched at Different Temperatures

Make and Type of Casing	Carbon, Per Cent	Quenching Temp., Deg. F.	Hardness, Bhn
X—A. P. I. Grade B	0.24	1600	212
X—A. P. I. Grade B	0.24	1700	241
X—A. P. I. Grade C	0.41	1500	600
X—A. P. I. Grade C	0.41	1600	600
X—A. P. I. Grade C	0.41	1700	600
Z—Low Alloy Grade C	0.30	1500	418
Z—Low Alloy Grade C	0.30	1600	387
Z—Low Alloy Grade C	0.30	1700	340

Table 4—Coupon Tests of Grade B Welded Casing Employing Water Quench

Type of Casing	Yield Point, Lb. per Sq. In.	Tensile Strength Lb. per Sq. In.	Remarks	Joint Efficiency, Per Cent
With Weld Reinforcement				
X—A. P. I. Grade B	48,000	76,000	Failed in plate 2 in. from weld	126.7
X—A. P. I. Grade B	48,000	76,000	Failed in plate 2 in. from weld	126.7
With Reinforcement Removed				
X—A. P. I. Grade B	49,000	78,000	Failed in plate 2 in. from weld	129.9
X—A. P. I. Grade B	48,000	76,000	Failed in plate 2 in. from weld	126.7

MULTI-FLAME TIP DEVELOPMENT

As an indication of the efficiency of multi-flame tips, it might be stated that on heavy wall casing the over-all time per joint, using two operators, may be expressed in minutes equal to one-half the nominal diameter of the casing in inches. In other words, a 5-in. casing will require $2^1/_2$ minutes on the average, and for a 7-in. casing, $3^1/_2$ minutes. Even greater speeds can be obtained with light wall material. These welding speeds equal or better competitive applications and compare favorably with the time for screwing couplings.

Table 5—Coupon Tests of Welded Casing Employing a Copper Block Quench

	Yield Point, Lb. per Sq. In.	Tensile Strength, Lb. per Sq. In.		Joint, Efficiency, Per Cent*
With Weld Reinforcement				
X—A. P. I. Grade B	47,000	78,000	Failed in plate 2 in. from weld	129.9
X—A. P. I. Grade B	47,000	78,000	Failed in plate 2 in. from weld	129.9
X—A. P. I. Grade C	63,500	93,500	Failed in weld	124.6
X—A. P. I. Grade C	65,000	94,000	Failed in weld	125.4
Z—Low Alloy Grade C	60,000	82,000	Failed in weld	109.0
Z—Low Alloy Grade C	61,000	83,000	Failed in weld	110.2
With Reinforcement Removed				
X—A. P. I. Grade B	48,000	78,000	Failed in plate 2 in. from weld	129.9
X—A. P. I. Grade B	48,000	78,000	Failed in plate 2 in. from weld	129.9
X—A. P. I. Grade C	64,000	94,000	Failed in weld	125.4
X—A. P. I. Grade C	65,000	94,000	Failed in weld	125.4
Z—Low Alloy Grade C	62,000	84,000	Failed in weld	111.5
Z—Low Alloy Grade C	61,000	82,000	Failed in weld	109.0

* Based on specification of minimum tensile strength (see Table 2).

There has been in the past, when welding was not so generally accepted, some concern about the quality of the joint produced because of the so-called "human element." With multi-flame welding, the design of the welding heads and manipulative technique is such that consistent fusion can be obtained for 90–95% of the wall thickness through heat balance or equilibrium inherent in the preheating and fusion of the base metal, the preheating and melting down of the filler rod. With reasonable supervision, training and qualification of operators, an efficiency of 80–90% may be expected. These efficiencies are so much higher than obtainable with mechanically coupled casing that oxyacetylene welding now offers a reliable means of replacing screw casing.

SPOT WELDING of ALUMINUM and Its Alloys with Low Current Welders

By G. Lo BUE

ABSTRACT

This article describes a process for spot-welding sheets of aluminum and its alloys, in which are used welders similar to those used in the steel industry. The process is based on the principle of increasing the electrical resistance of the surfaces to be welded by means of an oxide coating, which increases the heating effect.

An economical process for the anodic treatment of the sheets is also described and examples are given which show the physical properties, as well as the corrosion properties, of the welds.

* Translation by Dr. A. Di Giulio, University of Detroit, of "La saldatura elettrica a punti delle leghe di alluminio con bassa intensita di corrente," published in *Alluminio*, 7, No. 2, March–April 1938. Paragraphs on cost and other conditions of local importance have been omitted.

THE purpose of this research is to study the use of the regular spot-welding machines, as used for welding steel, in spot-welding sheets of aluminum. This is in spite of the fact that these machines operate at relatively low current. It is well known that, due to the relatively high conductivity of aluminum, it is usually necessary to use high current densities up to 50,000 amp. to cause the fusion at the place of contact. The process described is based on the principle of artificially increasing the electrical resistance at the surface of contact of the two sheets to be welded. This coating is so thin that it does not in any way decrease the corrosion resistance of the material but, if anything, increases it.

The presence of this zone of high electrical resistance at the place of contact produces the following results:

a. The fusion of the material with low current density according to the equation $Q = RI^2$.

b. The localization of the fused zone near the surfaces of contact, leaving the surrounding material entirely unchanged in spite of long application of current.

c. The possibility of using normal mechanical relays, since, as soon as the fusion has taken place, the low current which is used causes only a negligible secondary heating effect.

PREPARATION OF THE SHEETS

Without going into the large number of experiments carried out in order to produce this artificially resistant layer, we shall describe the method which gave the best results—namely, the anodic oxidation with a solution of oxalic acid using a brush for the application of the solution. As is well known, the anodic oxidation has been used to increase the corrosion resistance of aluminum and its alloys; hence, no danger is to be expected from this process. The use of the oxalic acid as the electrolyte avoids immersing the sheets in a tank, because since the oxidation takes place so readily, it can be carried out by means of a portable electrode, which is covered with felt and dipped in a 3% oxalic acid solution. The original experiments were carried out using 10 to 20 volts D.C. but later experiments proved that 40 to 80 volts gave better results.

It is also noted that with 80 volts the oxidation of the surfaces is so rapid as to allow the brush to be moved with a velocity of 4 to 8 in. per second, and the resulting oxide layer is of an optimum thickness. In order to facilitate the carrying out of the operation, A.C. current can be substituted for D.C. very successfully. The pieces to be treated are placed on a grounded aluminum table which is connected on one side to a transformer (1 kw.—80 volts), while the other side of the line is connected to the electrode which is made up of a piece of graphite covered with a layer of felt, the upper part of the graphite piece being covered with rubber or any insulating material in order to avoid a loss of current. A handle also of insulating material is attached to facilitate the operation. The thickness of the oxide layer obtained by this process is of the order and magnitude of one micron or less. The layer is perfectly adherent, flexible, hard and will stand considerable rubbing in handling. Its color is a milky white, resembling duralumin after the pickling. This fact suggested the idea of replacing the pickling process of duralumin with the oxalic acid process, thus obtaining corrosion resistance and the possibility of spot welding.

THE OPERATION OF THE MACHINE

In all the experiments here reported, a regular 10 kva. spot-welding machine was used with hydraulic controls, which permitted close regulation of its operations.

Best results were obtained by using a pressureof 132 lb. between the electrodes, which is not much different from the pressure commonly used in the welding of iron and steel. This pressure can be kept constant for each particular machine by a calibrated spring system.

For sheets 0.020–0.039 inch thick, the diameter of the electrode may vary between 0.11 and 0.14 inch and the time may vary from $^1/_3$ to $^1/_5$ second. If the surface of the sheets of aluminum is rough or dirty, it may be advisable to clean it by any suitable means; but, in general, the finish of the sheets is good enough without any further treatment. It is also possible to superimpose several of these sheets and thus weld up to three or four of them together.

STRENGTH OF WELDS

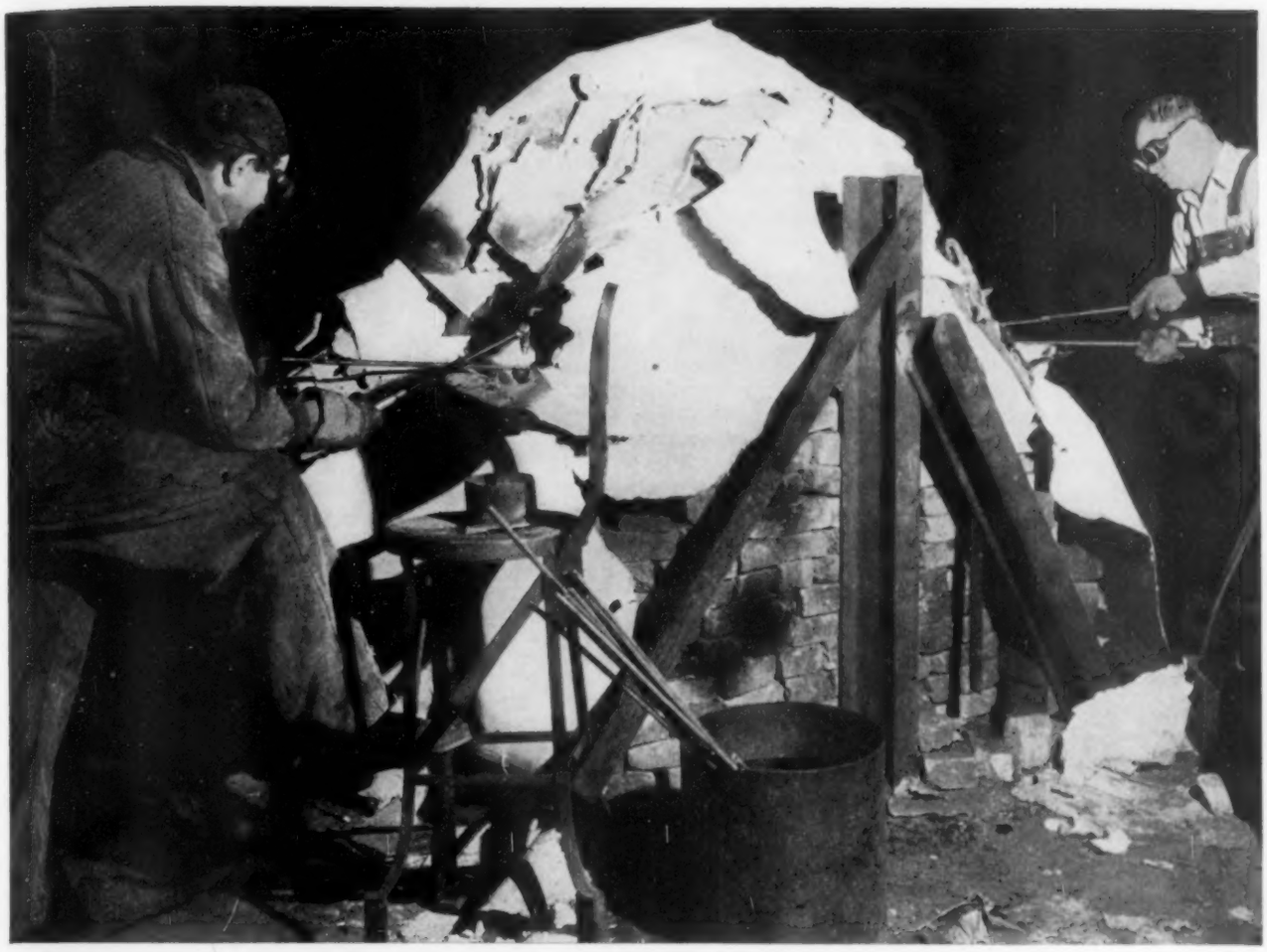
The shearing strength determination was carried out on samples of duralumin 0.039 inch thick, spot welded in two places 0.32 inch apart. The welding was done under the following conditions: pressure, 132 lb.; time, $^1/_5$ second; diameter of the electrodes, 0.12 inch. The values obtained varied from 375 to 420 lb. This strength is higher than the strength obtained by using a 0.12 in.-rivet, as is generally done now. If the time of welding is increased to about 1 second, the strength of the welds is decreased to about 330–350 lb. If the time is kept at $^1/_5$ of a second and the pressure between the electrodes is reduced to 90 lb., the strength of the welds will vary from 310 to 330 lb. However, it is not advisable to increase the pressure above 132 lb. in order not to decrease the electrical resistance between oxide layers. The pressure applied in these experiments, using electrodes 0.126 inch diameter, gives a value of about 11,500 lb./in.^{2} of tip surface. If the diameter of the tip is increased, it is necessary to increase proportionally the pressure and the voltage. The tests above mentioned were carried out about four days after the welding operation. If they are carried out as soon as the welding is done, the results will be from 20 to 25% lower, which indicates that the effect of the thermal treatment produced by the welding continues for a considerable length of time after the mass is cooled. This, of course, is confirmed by the subsequent microscopic study. With sheets of thickness less than 0.039 inch, the strength of each spot decreases to about 175–200 lb., which is well equivalent to the strength obtained by using a rivet of 0.08 to 0.10 inch diameter. With sheets of greater thickness, one must use proportionally larger welders and the machine which we had at our disposal only permitted us to work with thicknesses up to 0.039 inch thick.

CORROSION RESISTANCE

The corrosion resistance of the area which was welded is not in any way impaired. The structure of the sheets at the surface of the weld is not in any way changed. Photomicrographs show that the change in structure has only taken place within the thickness of the sheets and the effect has not reached the surface. It was thought that the periphery of the weld was liable to corrode and for this reason it became necessary to determine the corrosion resistance of those areas. Tests were run and slowed that welds subjected to a corrosion test with the same substance and for the same length of time failed if welding were not properly controlled. Welds which were properly controlled did not undergo any corrosion. Inspection in this case can be carried out by the naked eye and defects due to poor welds are quite visible.

CONCLUSION

The process of resistance welding of sheets of aluminum covered with an artificial oxide layer is practicable. The welders which can be used are basically the same as those used for sheet steel. The operating conditions are not very critical and good results can be *constantly obtained*. The oxide coating which must be produced on the surface is easy to obtain, and it is not costly; and what is more important, it adds to the corrosion resistance of the material. The strength of the welds obtained with sheets up to 0.039 inch thick is greater than the strength obtained with rivets now in use. This process has also been used for continuous spot welding (seam welding), and we are now experimenting with sheets of considerably greater thickness.



Careful Preheating with a Charcoal Fire and Slow Cooling Assured the Success of This Cast-Iron Welding Job. The 2½-Ton Casting, Supported by a Welded Steel Framework, Is Encased in a Fire-Brick Furnace and Covered with Asbestos Paper

WHEN AND HOW TO PREHEAT

A Review of the Principles and Practices Involved in Preheating Certain Metals Before Welding

By C. C. NOTEBAERT*

IT IS a well-known fact that all metals expand when heated and contract on cooling. When any flame, or heat from any source is applied to metal, uneven heating will cause uneven expansion, and uneven cooling will cause uneven contraction. Under such conditions stresses are set up within the metal. Although ductile metals, such as steel, seldom suffer serious strain during expansion and contraction, non-ductile metals, such as gray cast iron, may develop stresses which, if of sufficient magnitude, will cause distortion or possible fracture of the part. The application of preheating, however, as a preliminary step in welding affords a means for avoiding or relieving expansion and contraction stresses. It is the purpose of this article to review briefly the fundamental principles and practices involved in preheating some of the commoner metals.

The net result of heating and cooling is determined largely by the shape, size and design of the parts being welded. In welding together the pieces of a broken grate bar, for example, the effect of heating and cooling will not cause any difficulty because the bar is entirely free to expand and contract. Very few of the parts that require the operator's attention are as simple as this, however. The operator is constantly called upon to repair broken parts of irregular shape and intricate design, or to join sections of quite different thicknesses. All such work and, in fact, practically every job that an

* The Linde Air Products Co.

operator undertakes requires a thorough, practical knowledge of the effects of expansion and contraction.

Provision for the relief of contraction stresses is particularly important where welds are to be made in parts that are confined at each end, such as the spokes of a wheel or pulley. Unless proper precautions are taken, the contraction stresses set up by the cooling weld may be great enough to fracture the spoke. By proper preheating, a body expands in all directions, and the heat of welding becomes a minor force. When the part is subsequently allowed to cool slowly either in a furnace or in an annealing bin, the contraction also will be in all directions and there will be little or no resulting stress.

OTHER REASONS FOR PREHEATING

There are two other important advantages which result from preheating, in addition to the elimination of stresses which might otherwise be caused through uneven heating and cooling. The first is that the time required for welding a hot piece of metal is considerably less than that required if the metal is cold.

The second reason is that with certain metals, notably cast iron, a weld made on metal properly preheated and slowly cooled can easily be machined, whereas a weld which has been made on cold metal and cooled too suddenly may be hard and brittle and machinable only with difficulty. Proper preheating and subsequent annealing have the additional advantage of relieving stresses which may have been set up during the original casting of the metal.

PREHEATING METHODS

Various types of apparatus and agencies are employed for preheating. The selection of one type or another depends, of course, upon whether the preheating is to be general or purely local. The simplest form of local preheating is that which is accomplished by the oxyacetylene blowpipe flame itself. If the part to be welded is small and the ends free to expand and contract, it is only necessary for the operator to play the blowpipe flame over the metal around the part to be welded before the actual welding is done.

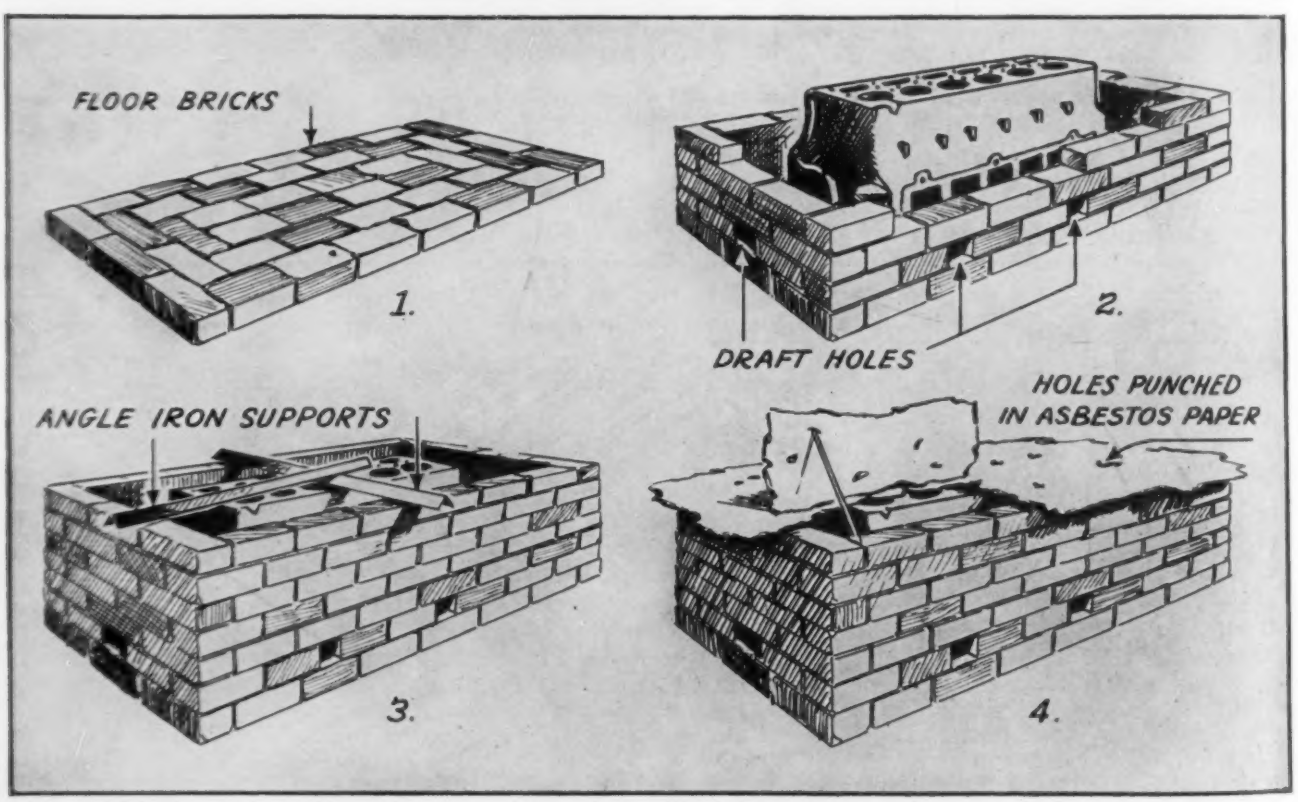
If a forge fire is available, it provides a very convenient means of preheating metal. Care must be taken, however, that the blower is used only enough to keep the fire going and that too much heat is not applied to the metal. It is advisable to protect the metal from any possible drafts with a covering of asbestos paper.

Many types of preheating torches burning kerosene, fuel oil, natural gas or city gas are available for local preheating on large pieces of metal and for the general preheating of smaller castings.

For general preheating where many similar large castings are to be welded, permanent preheating furnaces should be employed. These are usually fired with either natural or city gas.

TEMPORARY BRICK FURNACE CONSTRUCTION

The most common preheating agency for general preheating is the temporary fire-brick furnace, fired with charcoal. Charcoal is a most effective preheating fuel as it requires no forced draft to burn and its combustion give a steady, constant temperature. No soot or smoke is given out, which might otherwise deposit on the metal and hinder the welding operation. Temporary fire-brick furnaces are sometimes fired with gas, oil or kerosene preheating torches instead of charcoal. Coke should not be used as a fuel, as it gives too high a temperature and too localized a heat.



Steps in the Construction of a Temporary Fire-Brick Furnace. (1) Floor Bricks Are Laid Closely Together. (2) Draft Holes Are Provided in the First Tier. (3) Walls Are Built Up Higher Than the Casting. (4) Perforated Asbestos Paper Is Used as a Cover

This Compressor Head Was Cooled Slowly for 36 Hr., After Repair by Welding. Observe the Precision with Which Temporary Furnace Has Been Built

The temporary brick furnace is constructed by laying the bricks up around the casting. Enough space should be left between the brick wall and the casting to take care of the fuel and to permit handling the casting if turning is necessary during welding. First, the floor should be built with the bricks laid tightly together. Then the walls should be constructed, care being taken that a 2-in. space is left at intervals between the bricks on the first tier to provide draft. The walls should be built just above the top of the piece to be welded. After enough charcoal has been added to surround the casting completely, asbestos paper should be laid over the top. The asbestos paper should be supported on bars or light angle iron and should be punched with several small holes so as to produce sufficient draft.

To start the fire, the oxyacetylene blowpipe flame should be held for a few seconds at each draft hole at the bottom of the brick wall. The section of the metal to be welded should be near the top of the furnace, so that when the proper preheat temperature has been reached the asbestos paper covering may be drawn back sufficiently to permit welding to be carried on in a convenient position.

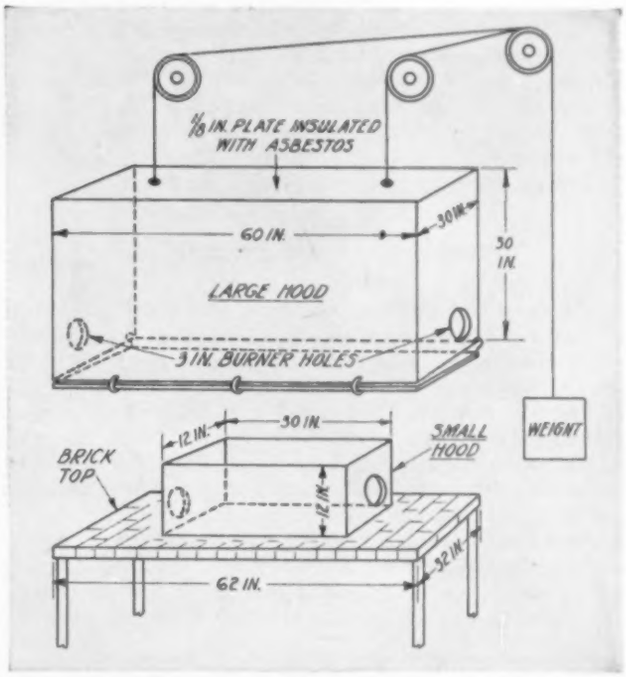
The design of a temporary furnace will, of course, vary with each piece to be preheated, and depends on the size, thickness and type of metal. For instance, with very large and heavy castings it may occasionally be necessary to use more than one thickness of bricks in making the walls of the furnace.

A SHEET METAL PREHEAT FURNACE

The accompanying sketch illustrates an interesting preheating setup which a welding shop has developed for handling a variety of castings such as automobile cylinder blocks.

If a small block is to be welded, it is merely placed in the small preheating box shown on the brick-top table. After the casting has been placed in position so that the veed sections are as near the top as possible, a cover is placed over the hood and two gas burners inserted in the holes at either end. Because of the position of these holes, the heat circulates around the block inside the hood. When the casting has reached a dark cherry-red (about 1200° F.) the top cover is removed and the welds made with the gas burners still on. After welding, the burners are removed, the cover is replaced and the hood and block allowed to cool gradually.

The large hood suspended over the table is used for welding larger blocks and crankcases. It is made of $^1/_8$-in. steel plate and is insulated on the inside with asbestos. The casting to be welded is placed on the table and the hood lowered into position with the bottom door open. Gas burners are inserted in the holes and the casting is brought to correct temperature. Then the hood is raised and the hinged door at the bottom closed so as to protect the operator from the heat within the hood. The two burners are left on during welding. When welding is completed, the hood is lowered again over the casting and the whole allowed to cool slowly.



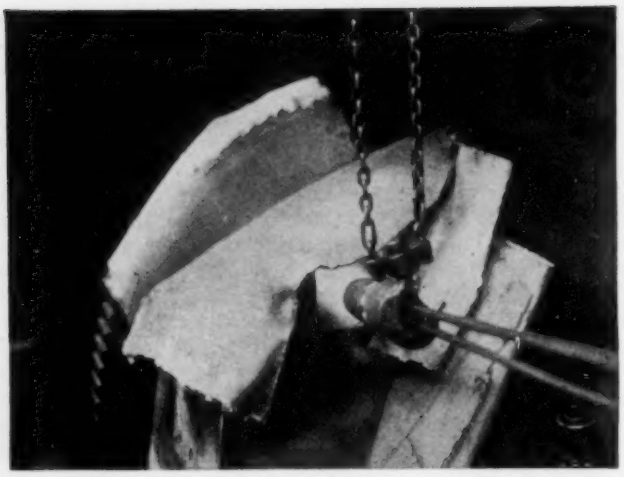
Automotive Castings Are Preheated Inside These Sheet Metal Hoods by Means of Gas Burners Extending Through the Holes in the Ends. The Hood on the Table Is Used for Small Castings

ANNEALING

After welding, preheated castings must be allowed to cool very slowly in order to avoid setting up internal stresses and to prevent the formation of hard spots.

Where castings have been welded in preheating furnaces, cooling should take place right in the same furnace. After the weld is finished, fresh charcoal should be added, and all the openings in the furnace should be plugged to keep out the air. As the casting cools slowly, contraction is uniform, and all internal stresses are relieved.

For smaller castings, it is well to provide an annealing bin. This is simply a fireproof box filled with some heat-insulating material, such as dry asbestos fiber cement,



Local Preheating with This Gas Burner Permitted Bronze-Welding Repair without Dismantling the Machine

hydrated lime or small bits of used asbestos paper. The hot casting should be quickly buried in this material and left there until cold.

Annealing bins may be of various sizes and shapes. A sheet metal bin is better than wood and a box of second-hand sheet metal with the cover attached by hinges is easily constructed by welding. Another excellent type of annealing bin for small parts can be made from an old range boiler. All that is necessary is to cut out about a 90-deg. section of the cylindrical surface with the cutting blowpipe.

PROCEDURES FOR CAST IRON

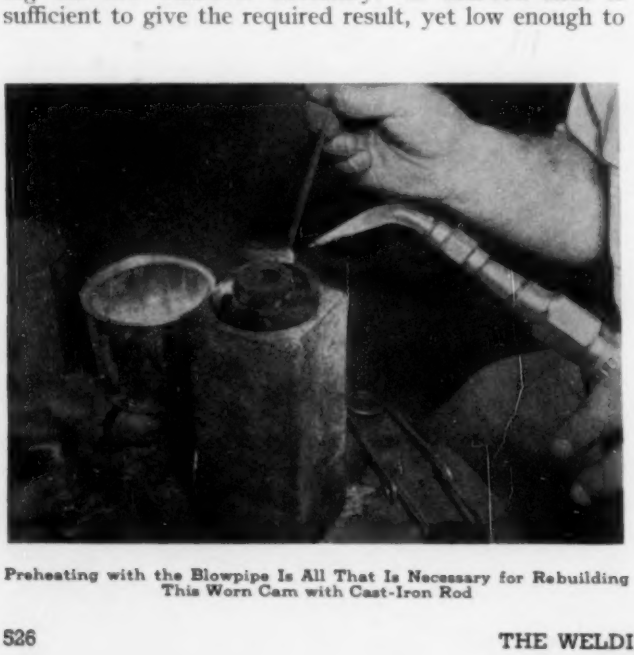
The most frequently encountered metal which requires preheating before welding is cast iron. Particularly when welding is done with cast-iron welding rod, the whole casting must be preheated in a furnace, or a sufficiently large section of the cast iron must be preheated locally. The part to be welded should be uniformly raised to a dull red color and then welded in the preheating furnace. This means that the fire must be watched and regulated by closing or opening draft holes, moving hot coals from one place to another, or replenishing the fire wherever necessary. A dull-red heat is sufficient to give the required result, yet low enough to prevent harm to the casting. If the metal is heated too much its own weight may warp it.

Heavy castings which have no thin members can be preheated to a slightly higher temperature. If there are thin members in the casting, however, they will heat up more rapidly than thicker sections, and care must be taken to see that they do not overheat and get out of shape. This is because the hotter sections must expand, yet may be held back by the heavier part of the casting which may barely be at a black heat. To overcome this when using a charcoal-fired furnace, more fuel should be placed around the heavier sections, or the casting should be so placed in the furnace that the heavier parts are closer to the charcoal than are the lighter sections.

If the casting is allowed to cool slowly after welding, the cast-iron weld metal will be found to be readily machinable.

When cast iron is bronze-welded, less preheating is required. Since the melting point of bronze is lower than that of cast iron, it is not necessary to bring the casting up to such a high temperature for welding. The use of local preheat is all that is generally required for the successful bronze-welding of cast iron. This means that large pieces of machinery need not be dismantled in order to make repairs.

Only the Fractured End of This Cast-Iron Heater Section Was Placed in the Charcoal Forge Fire During Repair by Bronze-Welding



Preheating with the Blowpipe Is All That Is Necessary for Rebuilding This Worn Cam with Cast-Iron Rod

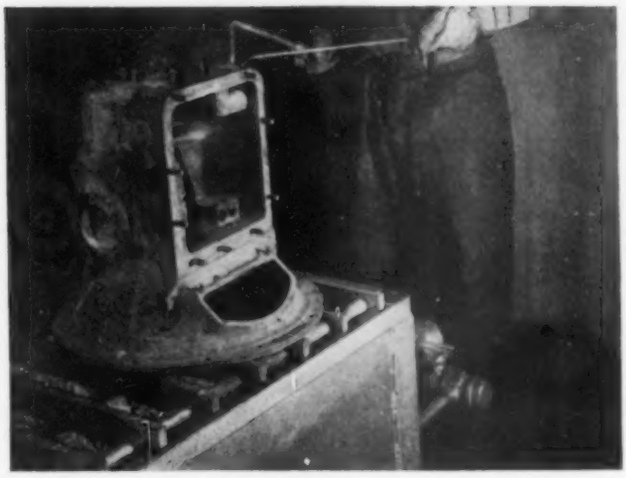
NON-FERROUS METALS

Non-ferrous metals, whether in the form of sheets, plates, pipe or castings, require much the same consideration as just outlined for cast iron. In addition, several non-ferrous metals and alloys, notably copper, aluminum, nickel and monel metal, possess a peculiar property known as hot-shortness. This means that there is a condition of low tensile strength and low ductility in a temperature range below the melting point. Monel metal, nickel and high-nickel alloys have a hot-short range between the temperatures of 1450 and 1650° F. Both above and below this hot-short range, these metals regain their strength and ductility. Aluminum has a similar hot-short range at a somewhat lower temperature.

Because of this property, particular attention must be given to expansion and contraction in welding these metals. Care should be taken to see that there are no undue stresses set up or existing while the weld metal and adjacent base metal are passing through the hot-short range as the weld cools. Parts will frequently require some form of support so that they will not distort under their own weight.

Table 1—Preheat Data for Some Common Metals

Metal	Preheat Temperature, ° F.	Temperature Color	Remarks
Gray iron castings (Cast iron welding)	1200	Dull red	Preheating the entire part in a furnace is recommended for all except small castings
Gray iron castings (Bronze-welding)	Hand-warm to 1000	Black	Local preheat to a black heat is all that is generally required. The extent of heating depends on the size and shape of the casting
Aluminum castings	350 to 450	Black	When the metal is hot enough to char sawdust, preheat is sufficient. Large castings should be well supported in the furnace
Nickel and monel metal castings	1200	Dull red	Castings should be well supported and constant preheat temperature maintained during welding
Bronze castings	1200	Dull red	Large castings should be preheated in a furnace. Otherwise, preheating not normally required
Steel castings	1200	Dull red	Preheating not usually required except for large castings of intricate design



A Permanent Gas Oven Affords a Ready Means for Preheating Aluminum Transmission Cases During Repair by Welding

CAST ALUMINUM

Cast aluminum is a metal which always requires a certain amount of preheating before any welding is attempted. In most cases, general preheating should be employed, with the whole casting placed in a preheating furnace and brought up to the correct heat.

More care is necessary when preheating cast aluminum than with almost any other metal. The control of the preheat and the proper regulation of the draft require the constant attention of the operator because of the peculiar properties of the metal. Aluminum is relatively weak when heated, and overheating may cause the casting to collapse of its own weight. For this reason, adequate support should be provided for the casting in the furnace. The temporary fire-brick preheating furnace, previously described, is the most satisfactory method for the general preheating of cast aluminum. If this type of welding is a routine matter in production work, a permanent furnace is recommended.

Preheating should be done very slowly in all cases, and the temperature of the casting must be carefully watched. Except in the dark, aluminum does not show a red heat before reaching the molten state. It becomes pasty, and it is difficult to tell merely from the surface appearance whether the casting has reached the proper temperature. When the casting has become hot enough to char sawdust, it is hot enough to weld. On small pieces, local preheating with a blowpipe will be sufficient to bring the edges to the proper heat. Besides the test with sawdust, the condition of the casting can be tested by scraping the surface of the metal with a steel rod to make sure that it is not becoming too soft. A cold casting should be brought up to the proper temperature very slowly, average time being about 30 min.

MONEL METAL AND PURE NICKEL CASTINGS

Castings of pure nickel or monel metal are quite sensitive to sudden temperature changes, and general preheating in a furnace is essential to the successful welding of these alloys. As in the case of cast aluminum, it is necessary to give the casting proper support while it is in the preheating furnace so that it will not distort or collapse under its own weight. Pure nickel or Monel metal castings will, however, show a dull red heat when a temperature of about 1200° F. is reached. This is the proper temperature to which the casting should be brought before welding is started, in order to eliminate both uneven heating stresses and excessive oxidation which may result from the local overheating of the metal. A steady, dull red heat should be maintained as far as possible during the welding operation. The lack of strength of the metal when hot should be kept in mind.

BRONZE CASTINGS

Bronze castings vary so widely in composition and metallurgical characteristics that it is difficult to give a specific preheat procedure to apply to all cases. In general, whenever the casting is of considerable size, preheating should be used and should be done in a furnace. Bronze castings become a dull red color when sufficiently preheated.

CAST STEEL

Because of its ductility and toughness, steel is a metal which rarely requires any preheating. A good steel casting will bend considerably before breaking, and an examination of any broken steel casting will show that it has undergone quite a considerable distortion before finally breaking. Small steel castings require no preheating at all. Large castings, however, with thick walls of such design that localized heat of welding might set up stresses in the steel should be preheated to a bright red color before welding.

Annual Meeting

A. W. S.

in conjunction with

National Metals Exposition

CHICAGO

Oct. 22-27, 1939

The Value of ELECTRIC ARC WELDING IN DESIGN and Its Limitations*

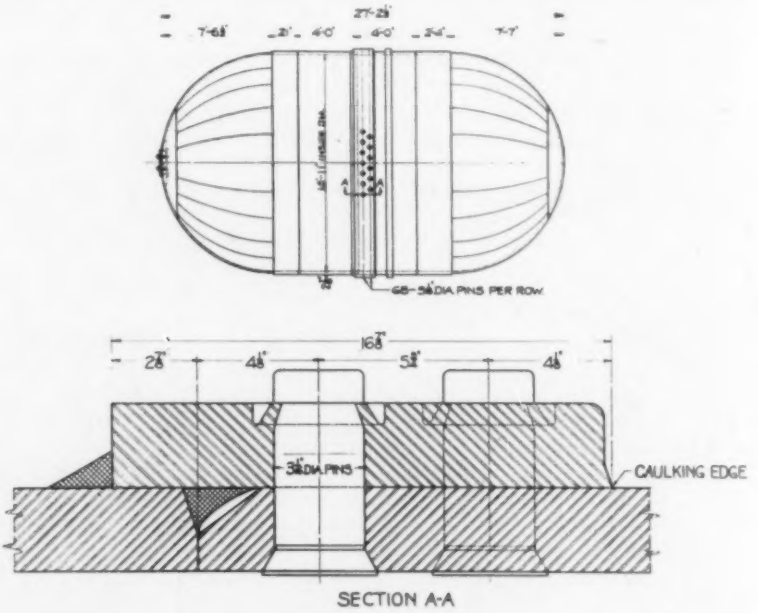
By ISAAC HARTER,† J. C. HODGE‡ and G. J. SCHOESSOW‡

IN THIS paper, as its subject indicates, we are concerned only with electric arc welding in which covered electrodes or their equivalent are used to obtain a ductile weld; and the word "welding" as used herein is to be understood in this restricted sense. Welding of this kind came into use about 1925, and together with other welding processes and the cutting torch, transformed our ideas of the fabrication of metal structures of almost every kind. At the same time, great economies have resulted, and sizes and kinds of structures have been made possible that have vitally affected whole industries. In the construction of buildings, bridges and similar structures, this country has not made use of welding to the extent that it has been used abroad. On the other hand, our use of welding for pressure apparatus has been incomparably greater than that of other nations. The general reason for this, in so far as structures are concerned, probably lies in the respective values of the ratio of material to labor here and abroad. In the case of apparatus, the same factor has its part in more general use of forgings abroad. We believe, however, that the difference in the weight and size limitations of railroad transportation available to us here, in conjunction with the large scale on which many of our chemical and similar industries operate, has also contributed to the great use of large welded apparatus in this country.

We are apt to accept a change in practice, such as that from riveted and bolted construction to welding, without realizing afterward the extent to which we have benefited and the position that we would be in if we attempted to do with the old art what we commonly practice with the new. It is, therefore worth while to consider examples showing the limitations of the old art and the advantages of the new, particularly where they occur in a striking way. At the same time, they emphasize that even with these advantages the new art also has its limitations.

Limitations of Riveted Construction

The welded penstocks at Boulder Dam began to be considered in 1931 at a time when riveting of such structures was still usual, and on account of the size of the work they furnish many worth-while comparisons. Boulder Dam penstocks were built with a design stress of 19,000 lb. per sq. in. with the requirement that this stress would not be exceeded throughout the structure in all of its details. The compliance with this requirement was



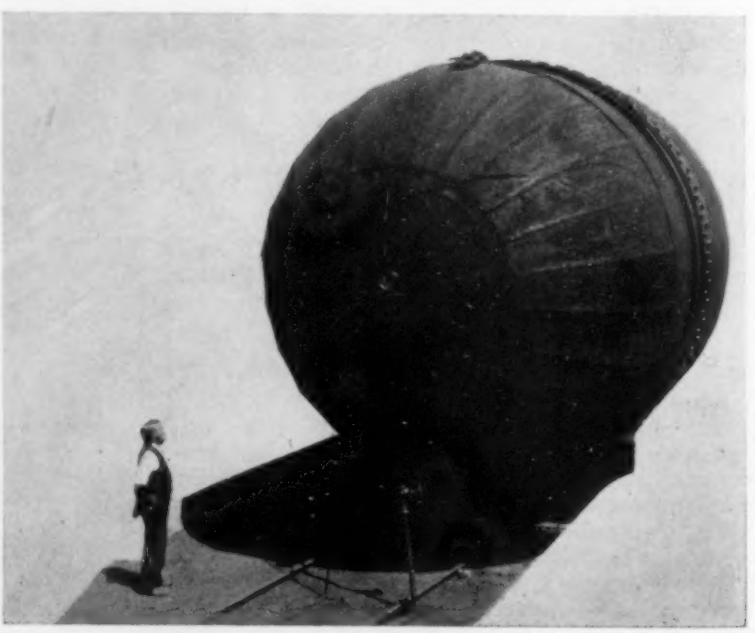


Fig. 1—Riveted Girth Joint Test Model (15 Ft. Diameter—2⁷/₈ In. Plate)

* Paper read before the General Meeting of American Iron and Steel Institute, at New York, May 25, 1939.

† Vice-President, The Babcock and Wilcox Tube Company.

‡ The Babcock and Wilcox Company.

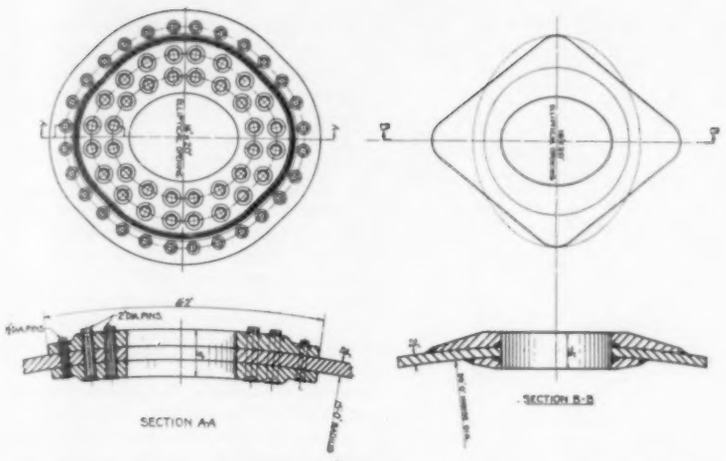


Fig. 2-A—Riveted Design Manhole Reinforcement for Elliptical Manhole in Large Diameter Pipe

Fig. 2-B—Welded Design Manhole Reinforcement for Elliptical Manhole in Large Diameter Pipe

checked with 2-in. strain gages in the completed penstock. The severity of this requirement is appreciated when one realizes that the hoop tension in the penstock, due to internal pressure, is alone equal to 18,000 lb. per sq. in., leaving only a margin of 1000 lb. per sq. in. for all other additive stresses.

It is well known that the rules for riveted design are based on a method of computation which predicts the ultimate strength at rupture of the joint; and about one-fourth to one-fifth of this strength is used as a safe design load. The rivets or bolts are computed for a bearing stress against the side of the hole, a shear stress across the rivet, a tension stress in the ligament between holes, etc. There are left out of the design computations such factors as friction between plates due to endwise tension in the bolt or rivet, the shrink of the rivet from its bearing surface in the hole when a hot-driven rivet cools, the stress concentration that exists at the hole, eccentricity of the joint, absence of pure shear on the rivet, etc.

Those factors are very important in the function of a joint; and if the working load is such that slip will not occur in the joint, the load-carrying power is contained in those things that are not usually computed, rather than in the things that are. Consider a hot-driven rivet $1^1/_2$ in. in diameter driven at 1350° F. Assuming that the plates joined are at room temperature, the rivet will shrink in diameter upon cooling $0.0000083 \times 1^1/_2 \times (1350° -$ plate temp.) $= 0.016$ in. About half of this shrinkage, 0.008 in., may exist as actual clearance between the rivet and hole when the rivet is cold. The other half of the shrink is taken up by the continuing pressure on the cooling rivet. Thus, there would be no bearing between the rivet and the side of the hole when cooled, and the plates would have to slip 0.016 in. before the 0.008 in. would be taken up in both holes, and before there could be any bearing or shear developed.

Consider, further, a body-bound bolted joint, which when subject to load experiences a deformation due to the elastic compression of the bolt in bearing, shear deformation of the bolt, and corresponding compression of the plates. Such deformation may readily add up to 0.01 in. for a joint employing 2-in. diameter body-bound bolts. If this slip does not occur, the load on the joint must be transmitted by friction between the plates, and the bolts function as clamps. There is a rapid decline in the friction strength when plate thicknesses approach $2^1/_2$ in., rivet diameters $1^1/_2$ in. to 2 in., and grips 6 in. to 8 in. This decline is the practical limitation in the ability of the joint to carry its design load without slip, or, in the case of pressure vessels, without leakages. This frictional behavior is of great value in ironing out unequally distributed rivet loads, with a corresponding reduction in risk of failure from fatigue in many different kinds of service.

Experience with the design of a girth joint 15 ft. in diameter with $2^7/_8$-in. thick plates, for a working stress of 18,000 lb. per sq. in., has shown the need of allowing for the elastic behavior of the joint. Figure 1 shows such a joint, which under test leaked extensively at the caulked edge when the hoop stress reached 18,000 lb. per sq. in. The remedy used in the prototype of this model was to neutralize the effect of longitudinal forces by pre-stressing the pipe in compression.

Because of the limitations described above, riveted pressure vessels are generally limited to plate thicknesses of about $2^1/_2$ in. Riveted pressure vessels are, therefore, limited to 5 to 6 ft. in diameter

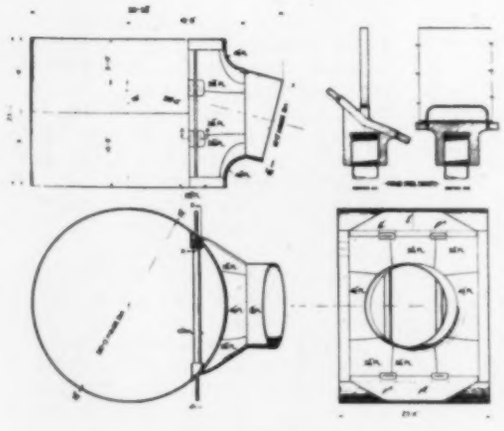
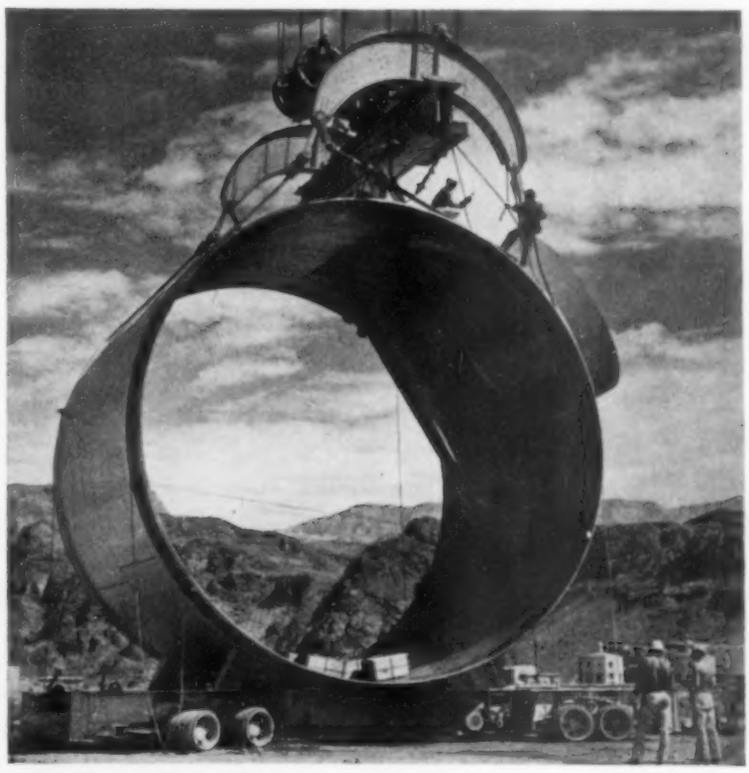


Fig. 3—30 Ft. Diameter Pipe with 13-Ft. Diameter Side Outlet



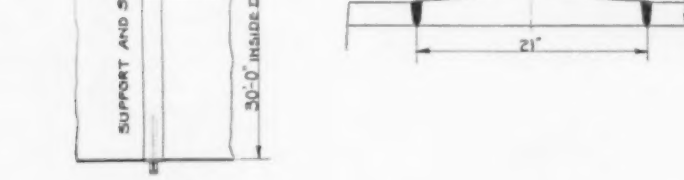


Fig. 4-A (Left)—Riveted Design of a Support and Stiffener Ring for Large Diameter Pipe Using Structural Shape and Plates

Fig. 4-B (Upper Right)—Welded Design of a Support and Stiffener Ring Actually Used for a Large Diameter Pipe

Fig. 4-C (Lower Right)—Riveted Design of a Support and Stiffener Ring for Large Diameter Pipe Using Special Rolled Shape

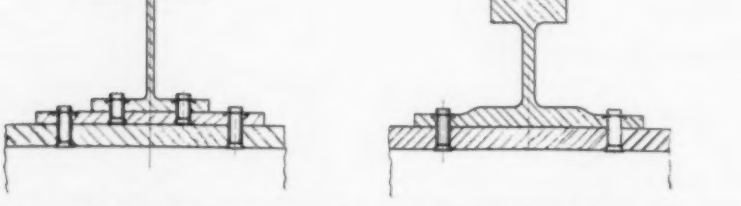


Fig. 5—Cast-Steel Flange Welded to Plate Steel Pipe

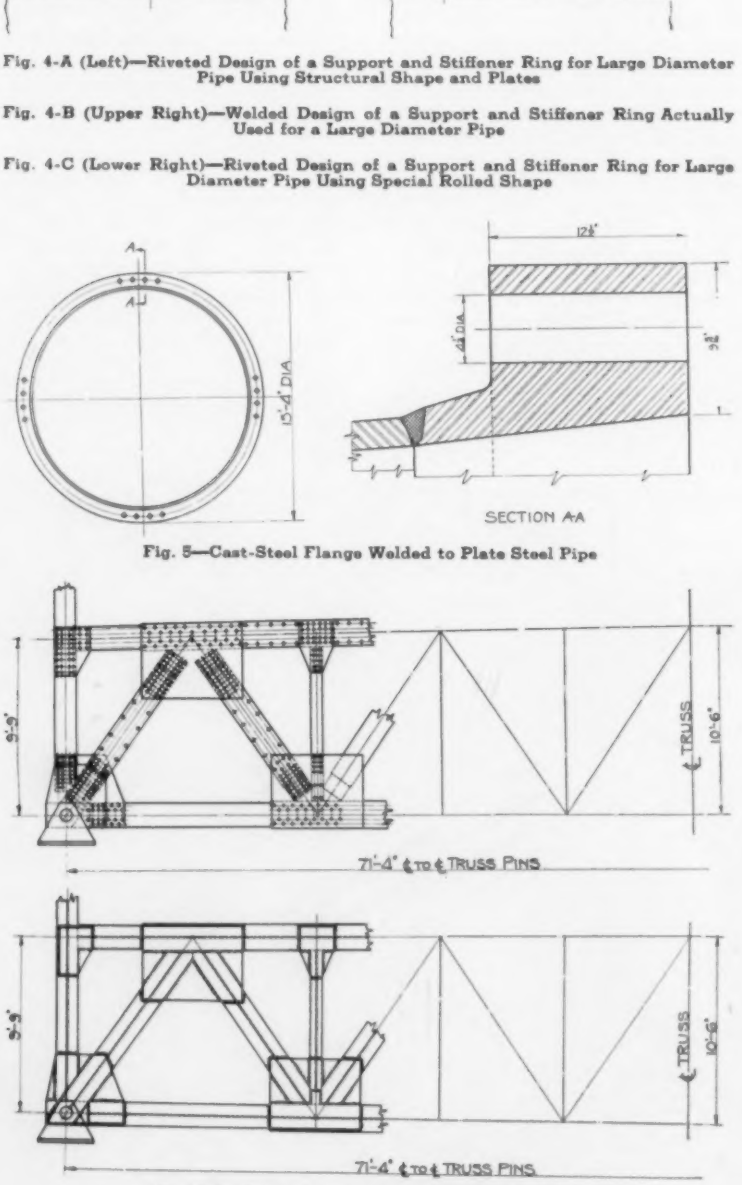


Fig. 6-A—Riveted Design for a Heavy Roof Truss

Fig. 6-B—Welded Design for a Heavy Roof Truss

for working pressures around 1000 lb. per sq. in. Before the advent of welding, forgings and forge-welded pressure vessels came into use mainly for this reason. Forgings, however, have the inherent disadvantages of relatively high cost, and a finished weight limit of about 70 tons which in many cases will not take care of the need. Today welded vessels can be made of unlimited weight and dimensions with plate thicknesses up to at least 6 in., and generally the size of the vessel is limited only by transportation facilities.

Advantages of Welded Design

For the Boulder Dam penstocks it would have been possible to construct a 30-ft. diameter riveted pipe, but at an increased cost of 20 to 25 per cent over welded construction. Smaller multiple pipe systems could have been used, but would have been still more costly. There would also have been an accompanying hydraulic disadvantage, which would have been a serious operating cost factor. Figure 1 shows the combination welded and riveted design actually used. To make the joint field-welded would have been a great simplification in construction and saving in cost. The problem of stress-relieving field girth joints was carefully studied and the studies checked by experiment. The conclusion was that for the dimensions involved the problem was an impossible one in so far as those engaged on it could determine. To leave the joint unstress-relieved was equally impossible for reasons detailed later in this paper. The elimination of half the rivets accounted for a saving of about 3 per cent in total penstock cost.

Riveted structures as compared with welded often fail to provide a determined and suitable path for stress flow. For example, Fig. 2-A shows the riveted man hole reinforcement required in a 30-ft. diameter pipe, and Fig. 2-B shows the actual construction used.

Figure 3 illustrates the 30-ft. diameter welded branch connection. This piece is subject to complete calculations in design and is in every way determinable as to its actions, stresses, etc. Calculations for these pieces were checked closely by strain-gage tests made on a one-fifth scale model. Some of the plates even for the welded design were $4^1/_2$ in. thick. It, therefore, seems likely that no satisfactory riveted design could have been made. Figure 3 also shows the junction piece between the branch connection, tie-rods and the cross-beams. The forged socket welded directly to all plate edges resulted in a fully X-rayable and rather simple design, whereas any other means of providing proper connection to the tie-rod would have been more complicated, or perhaps impossible. Figures 4-A and 4-C show riveted support and stiffener-ring constructions which would have been required, compared with the welded construction, Fig. 4-B.

Modern design emphasizes the importance of stress-concentration factors in all parts that have transition sections or abrupt changes in size. Welding, forgings and castings offer inherent advantages in providing easy transition contours. In

many instances it is economical to use a forging or casting in combination with welded construction, as, for example, the forgings shown in Fig. 3, or the cast-steel flanges shown in Fig. 5. In combination construction, castings preferably should be about the same composition as the plates, and special care should be taken to insure soundness in the welded region.

So far we have been dealing with welded pressure vessels. Here the economy of welding and accompanying structural advantages are so great that riveting has become almost obsolete for this purpose. Similarly for other purposes in this country, where the special advantages of welding are obvious as in barges, ships, pipe lines, etc., welding is rapidly being adopted and bids fair to become the universal method. The case for welding in this country is not by any means the same when it comes to structures such as buildings and bridges. The situation may be generally summarized by saying that in the past its development has probably been retarded by building code restrictions, by using the welding merely as a joining means for existing shapes rather than by redesign to make the most use of welding, and by not fully developing the appropriate shop methods. Perhaps the profound difference between shop welding and field welding has more than any other single factor limited the application of welding in structures. In shop welding, position welding can be minimized, uniformity of welding practice can be better assured, non-destructive testing can be more freely used, and an entire unit can ordinarily be stress-relieved. In the field the dilemma of leaving structures unstress-relieved or facing the difficulties and risks of local stress-relieving is always with us. As a result, there has been a strong and natural tendency to limit structural welding to component pieces, the dimensions of which permit complete fabrication in the shop. In contrast to

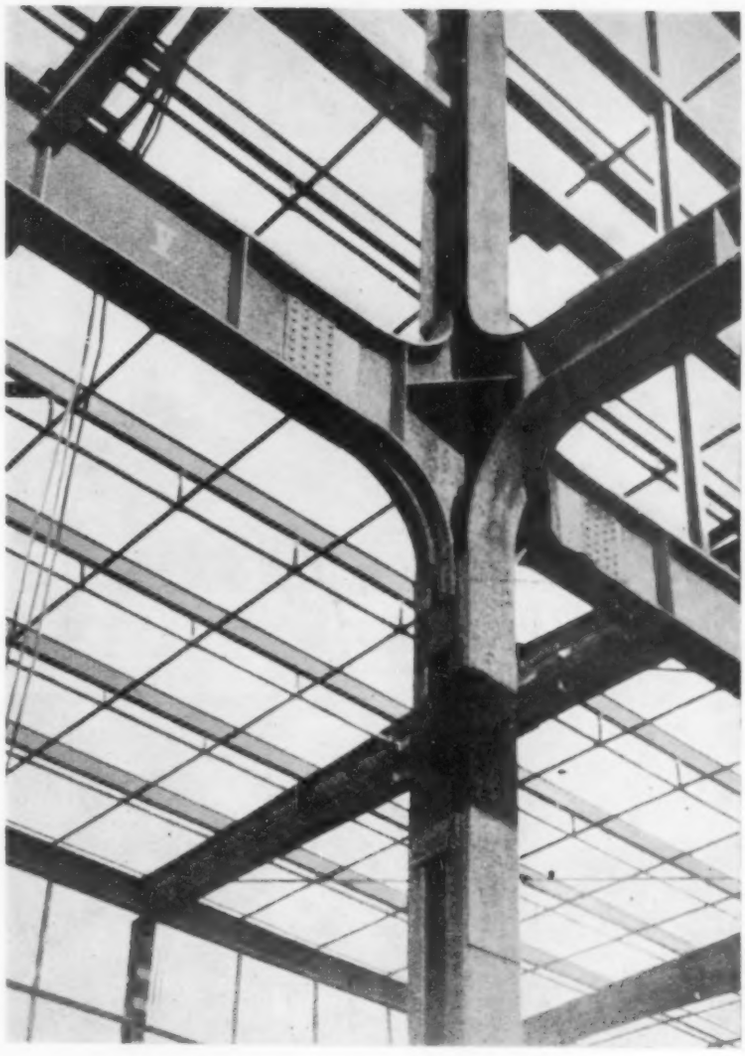


Fig. 7-A—Reception Hall of Main Railroad Station, Duisburg. Junction of Column and Beams

TABLE I

CHEMICAL ANALYSES AND TENSILE PROPERTIES OF TWO SERIES OF CARBON-MANGANESE STEELS

(with approximately constant yield point, 50-55,000 lb. per sq. in. in normalized condition)

Steel Designation	Carbon %	Manganese %	Silicon %	Ultimate Tensile Strength Lb./Sq. In.	Yield Point Lb./Sq. In.	Elongation in 2" %	Reduction of Area %	Mc-Quaid-Ehn Grain Size
Series I								
I-A	0.22	1.20	0.16	74,000	50,500	37	67	7
I-B	0.24	1.28	0.15	80,750	47,500	32	69	3
I-C	0.28	1.08	0.20	81,750	51,500	36	67	8
I-D	0.34	0.82	0.16	84,500	51,500	29	52	8
I-E	0.33	0.90	0.18	86,250	47,000	31	58	7-8
I-F	0.41	0.73	0.18	87,500	49,500	30	57	8
I-G	0.42	0.72	0.12	89,500	51,000	29	52	7-8
I-H	0.47	0.59	0.12	96,500	47,500	25	41	1-2
I-J	0.49	0.43	0.16	90,750	51,500	29	47	7
Series II								
II-A	0.21	1.64	0.21	83,000	56,000	34	72	7
II-B	0.39	1.05	0.17	103,250	57,000	26	50	4-5
II-C	0.43	0.93	0.13	96,000	55,200	30	53	8
II-D	0.52	0.71	0.14	101,000	54,000	23	40	7-8

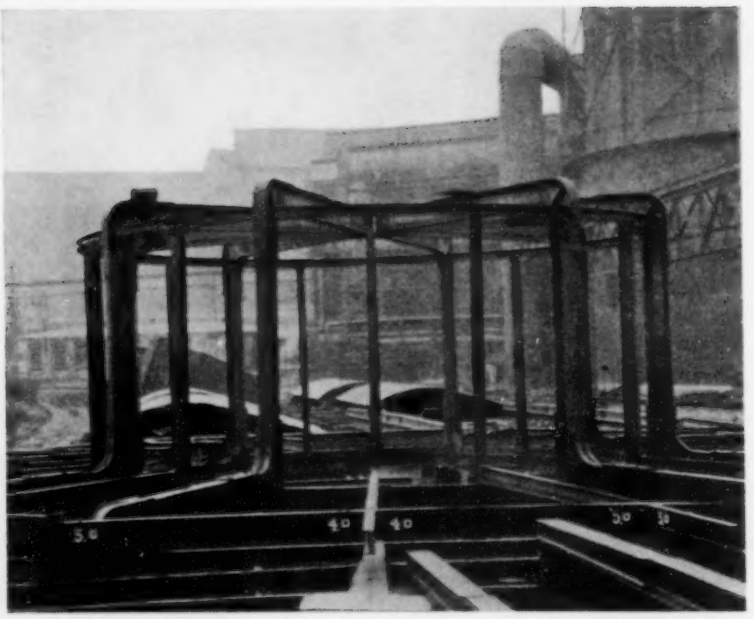


Fig. 7-B—Reception Hall of Main Railroad Station, Duisburg. Welded Construction of Skylight Dome

this situation, the use of welding to repair existing riveted structures is more generally accepted.

The weight savings of structural welding, in many cases, are surprisingly large. Figure 6-A shows a riveted roof truss typical of those in the roof of the Boulder Dam power house. Figure 6-B shows a welded design weighing 19 per cent less, notwithstanding that in this instance there were good reasons for treating the welding design essentially as a copy of the riveted construction, whereas further weight savings would have been possible if sections more suitable to welding could have been utilized. These trusses were built about six years ago. Today we have much more information and experience in controlling the distortion of large welded members which results from stress-relieving. We feel safe in saying that taking these two things into account these trusses today could be built welded more cheaply than riveted. We believe it likely that fundamental study in design and the factors controlling distortion will lead to much more extended use of welding for these purposes. In Europe economic conditions have favored welding for structural purposes, and Figs. 7-A, 7-B, 7-C and 7-D show the great degree to which they have progressed in working out appropriate welded designs.

Tubular members are ideal for compression loads. When properly stiffened they also make very stiff beams. They are well suited to arch bridge members when the function of the tubular members is properly treated. The elements of such a joint are the transfer of the direct load (compression in the case of deck structures, and tension for through spans) and the accommodation of moments. Figure 8-A shows the manner in which these actions may be cared for. Figure 8-B shows alternate constructions for different loading conditions. The spandrel column pierces the arch rib (for scale, the column may be 30 in. in diameter with a $^1/_4$-in. wall; while the main arch might for larger spans be 12 to 13 ft. in diameter with from $^5/_8$ to 1-in. wall). The column is pierced by

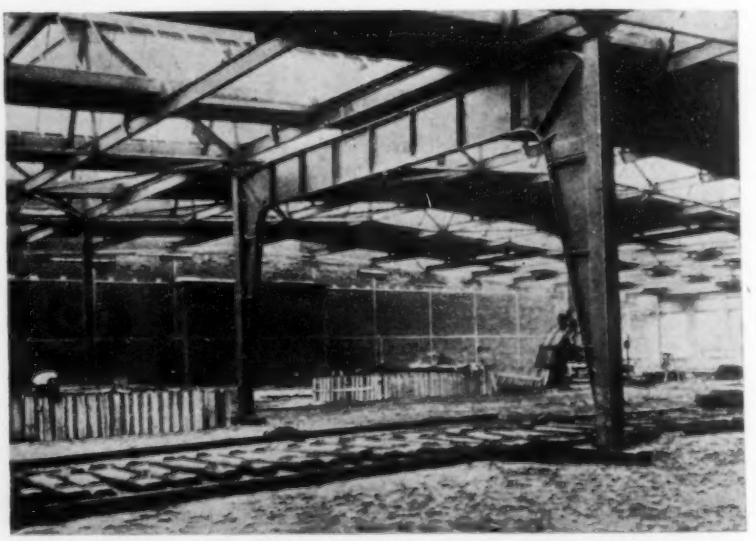


Fig. 7-C—Railroad Repair Shop, Niederschoeneweide. Welded Wind Load Portal

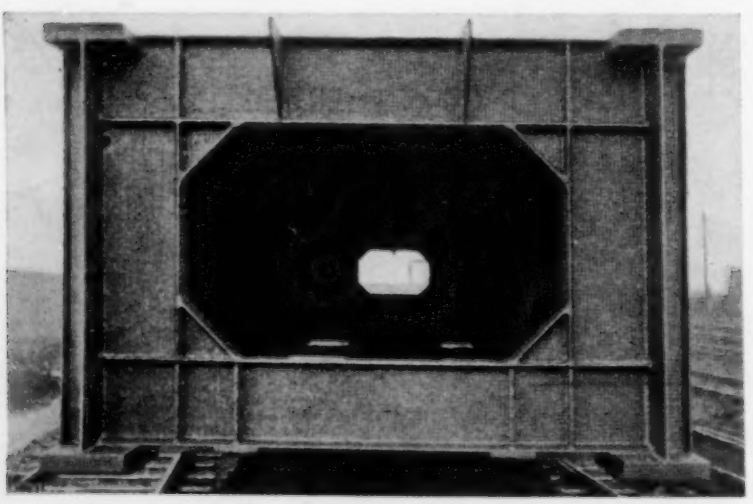


Fig. 7-D—End View of a Welded Plate Girder for 69-Ft. Span

a cross-girder which is attached to a stiffening ring and the column is welded to the arch shell. The load transferred to the stiffening ring at the girder ends is transferred via the stiffening ring to the rib shell through shear. Variations for light or heavy column loads may be developed along the same general lines. Likewise, tensile loads from hangers may be similarly accommodated as shown in the sketch.

Figure 9 illustrates a present-day application of large tubular members. In this design the inherent advantages of welding and also of tubular members have been utilized. The reader is referred to the original reference* for a complete description of this telescopic mount.

Weldments of rolled steel plate may, in many cases, be produced cheaper than castings, the basic advantage lying in the

* McDowell, C. S., "The 200-Inch Telescope," *Mech. Eng.*, 58, 345–351 (1936).

TABLE II

EFFECT OF COMPOSITION ON WELDABILITY OF CARBON-MANGANESE STEELS

Steel Designation	Bend Test (½" thick) (% Elongation of surface with weld bead)	Brinell Hardness (¼" thick)		Weld Quench Tests		
		Original Normalized Plate	Max. Hardness-weld affected zone	Charpy Impact Normalized Plate*	Charpy Impact Weld Quench**	Hardness Weld Quench
Series I						
I-A	36 34	162	240	15.0	24.0	195-200
I-B	21 26	179	260	27.0	17.0	219-296
I-C	21 23	170	252	23.2	7.6	254-296
I-D	13 13	175	265	9.0	3.5	235-254
I-E	17 25	185	265	19.7	6.8	204-235
I-F	16 13	179	280	15.0	6.7	219-244
I-G	15 15	179	288	12.5	2.5	235-273
I-H	8 8*	205	313	7.2	4.3	219-254
I-J	7 6*	195	313	9.0	3.0	254-286
Series II						
II-A	24 16	179	280	12.0	19.0	176-235
II-B	9 9	200	447	17.0	4.0	308-394
II-C	18 11	195	280	13.0	4.3	228-254
II-D	3 4**	205	340	7.5	1.7	286-414

NOTE:
* Average of three specimens. Specimens are ½ width of standard Charpy specimen.
** Longitudinal crack through weld on cooling.

relative cost of steel as rolled plates and as cast in molds. Weight saving is also attained by reason of the higher unit strength of rolled steel. Complicated shapes of plate material may be readily produced by torch cutting and incorporated into the part by welding. It has even been practical to pre-machine small parts on standard machine tools and to subsequently weld them into larger structures with sufficient accuracy of alignment to avoid the necessity of remachining the heavier structure on special tools. These major advantages, combined with other minor conveniences, such as elimination of patterns, have resulted in an appreciable use of weldments instead of castings. The extent of this substitution has been estimated to be of the order of 10 to 15 per cent. Weldment competition has among other things led the foundryman to better the quality of castings and he, himself, has used welded construction to advantage, welding together cast parts or castings to plates and shapes to form a unit construction more complex than could be produced as a single sound casting.

Technical Limitations of Welded Construction

While fusion-welded construction possesses advantages not shared by other constructions and has, therefore, resulted in structures of dimensions or service conditions beyond the limitations of older methods of fabrication, fusion welding has its own inherent problems, which are the causes of trouble and limitation of the art. All these limitations arise from the local application of welding heat, fundamental with all fusion welding processes. The deposited molten metal heats the adjacent plate material, establishing a thermal gradient from the melting point at the line of fusion to a much lower temperature at locations removed from the weld. Cooling of the deposited fusion metal and the adjacent parent metal subsequently occurs. In the usual fusion-welding process, cooling proceeds quickly, and microstructures are produced in the deposited metal and adjacent parent metal, dependent upon composition, maximum temperature attained and rate of cooling. Adverse structures and corresponding undesirable mechanical properties may be produced. Contraction of the locally heated zone results in distortion of the welded assembly and the establishment of residual stresses within it which may affect its serviceability. In the subsequent discussion of some of the more important limitations it will be evident that progress in avoiding many of the restrictive factors has been very small.

Weldability of Steels.—The weldability of a steel may be defined as its ability to pass through the thermal cycle of a particular welding technique without the production of hard or brittle zones in the welded joint, which would tend to the production of cracks or to the failure of the welded joints under service loading. All steels are sensitive to welding temperature; i.e., changes are produced in the plate material adjacent to the weld metal. Even in low carbon steels of approximately 0.25 per cent or less, which from a practical view-point may be considered as insensitive to welding temperature, a sorbitic structure with accompanying increased hardness is formed (Fig. 10-A and -B). Cracking occurred in the 0.44 per cent carbon steel, indicating that under the temperature and other conditions used in making these welds, the limit of weldability lay between 0.38 and 0.44 per cent carbon. This limit is substantiated by Fig. 11.

The presence of additive elements will enhance the hardenability of steel of a given carbon content, and more restricted weldability will be encountered. Individual elements effect increased hardenability to widely varying degrees, and for a given carbon content, weldability of a low alloy pearlitic steel will depend upon the quantity and particular combinations of the alloying elements present.

While the weldability of steel, as related to composition, may be generally predicted and steels roughly classified as weldable or non-weldable under normal welding techniques, exact knowledge of composition limits and of the relative effects under welding of various hardening elements is lacking. We may take the two commonest alloying elements, carbon and manganese, to illustrate our lack of precise knowledge of their weldability effects. Steel of approximately the same yield point and tensile strength after normalizing may be produced with compositions involving (*a*) relatively high carbon and relatively low manganese, (*b*) relatively high manganese and relatively low carbon, or (*c*) intermediate values of carbon and manganese. Table I shows two series of open hearth steels selected with respect to varying carbon and manganese contents to give the same yield point of approximately 50,000 to 55,000 lb. per sq. in. in ½-in. thick sections in the normalized condition. These steels were selected to throw some light upon this question. The steels of Series II possess for a given carbon content, manganese contents approximately 0.30 to 0.40 per cent higher than those of Series I. These higher manganese contents are reflected in the average higher yield points and tensile strengths of the second series. The relationship between the tensile properties and the chemical analyses of the steels of the two series is shown in Fig. 12. The pronounced effect of carbon in producing increase in tensile strength without corresponding increase in yield point is confirmed.

The weldability of these steels was then investigated under comparative conditions. Single beads of weld metal from

TABLE III-A

EFFECT OF PLATE TEMPERATURE ON WELDABILITY OF CARBON-MANGANESE STEELS
(½" thick plate specimens)
(Values represent % Elongation in Bend Tests)

Steel Designation	0°F.	32°F.	40°F.	50°F.	75°F.	110°F.	150°F.	300°F.	450°F.	750°F.	1000°F.	1200°F.
Series I												
I-A					36							
					34							
I-B	2				21							
	2				26							
I-C	3		13	21	21							
	4				23							
I-D					13	14	20	22	24			
					13							
I-E	3				17							
	4				25							
I-F	3				16			15	20			
	4				13							
I-G		3			15							
		2			15							
I-H					8	7	9	7	6	7	13	15
					8	9	10	8	7	10		
I-J		3			7							
		4			6							
Series II												
II-A					24							
					16							
II-B	2	19			9							
	1	3			9							
II-C					18							
					11							
II-D					3	4	4	4	4	10	10	11
					4	2	4	4	4	5		

$^3/_{16}$-in. diameter electrodes of a standard commercial type were deposited on the machined surface of $^1/_2$ and $1^1/_2$-in. thick plates of the dimensions shown in Fig. 13. In a large number of cases preheating above or cooling below atmospheric temperature was applied to the sample plate prior to welding. Weldability in all cases was judged by (1) bend tests, (2) hardness measurements across the weld on a transverse section and (3) macroscopic and microscopic examination of weld sections. The bend test specimens had the excess weld metal of the weld bead machined and ground flush with the plate surface, the specimen being then bent longitudinally with the weld surface in tension. Controlled bend tests were made; when failure did not occur after full bending in jig, the specimen was further bent as a free bend. For comparison with these actual weld tests, weld quench tests as developed at the Naval Research Laboratory as a measure of weldability* were made on the steels.

Considering only composition effects, comparative weldability may be best judged by Table II, presenting actual weld test data on $^1/_2$-in. thick plates welded without preheating or precooling. Ductility of the weld, as measured by the performance of the bend tests, decreases for each series of steels as the carbon content increases. Hardenability on welding as gaged by the maximum hardness in the heat-affected zone increases. The increase in hardness is quite uniform for Series I, but inconsistent maximum hardness characterizes the weld-affected regions of the steels in Series II. The Charpy impact values of the weld quench tests decreases for the steels of the two series.

* Bruckner, W. H., "The Use of the Charpy Test and Method of Evaluating Toughness Adjacent to Welds." *A. S. T. M.*

TABLE III-B

EFFECT OF PLATE TEMPERATURE ON WELDABILITY OF CARBON-MANGANESE STEELS
(½" thick plate specimens)
Maximum Brinell Hardness of Heat Affected Zones

Steel Designation	0°F.	32°F.	40°F.	50°F.	75°F.	110°F.	150°F.	300°F.	450°F.	750°F.	1000°F.	1200°F.
Series I												
I-A					240							
I-B	342				260							
I-C	360		340	296	252			265				
I-D					265	272	265	265	246			
I-E	370				265							
I-F	414				280			258	258			
I-G		414			288							
I-H					313	296	288	272	272	258	235	200
I-J		331			313							
Series II												
II-A					280							
II-B	542	494			447							
II-C					280							
II-D					340	331	313	313	304	288	263	242

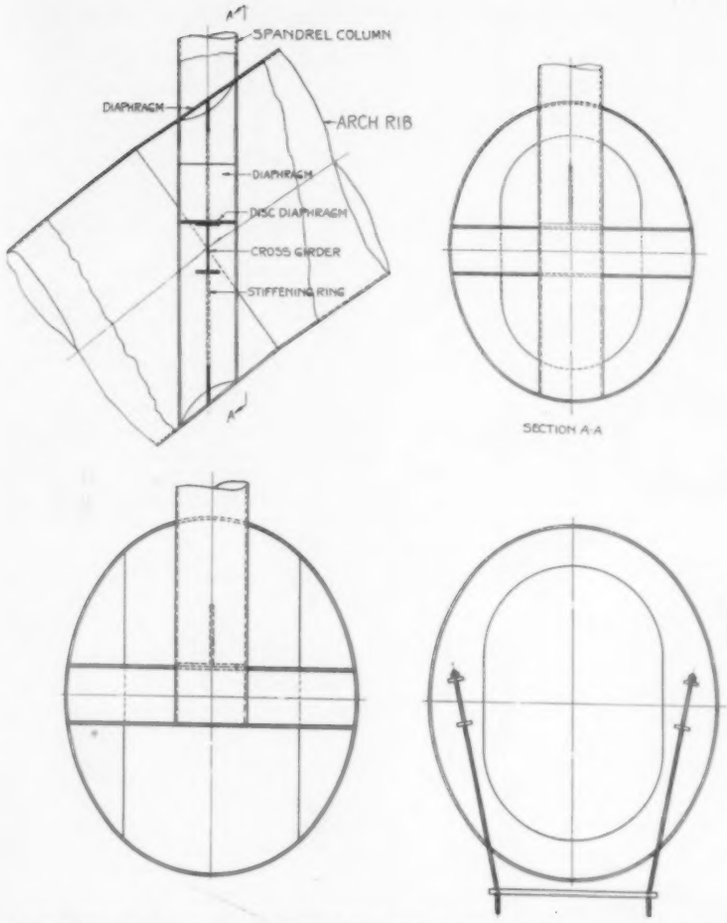


Fig. 8-A (Top)—Junction of Cylindrical Arch Rib and Spandrel Column for a Bridge. (Courtesy of S. C. Hollister)

Fig. 8-B (Bottom)—Sections Showing Alternate Constructions for Different Types of Loading. (Courtesy of S. C. Hollister)

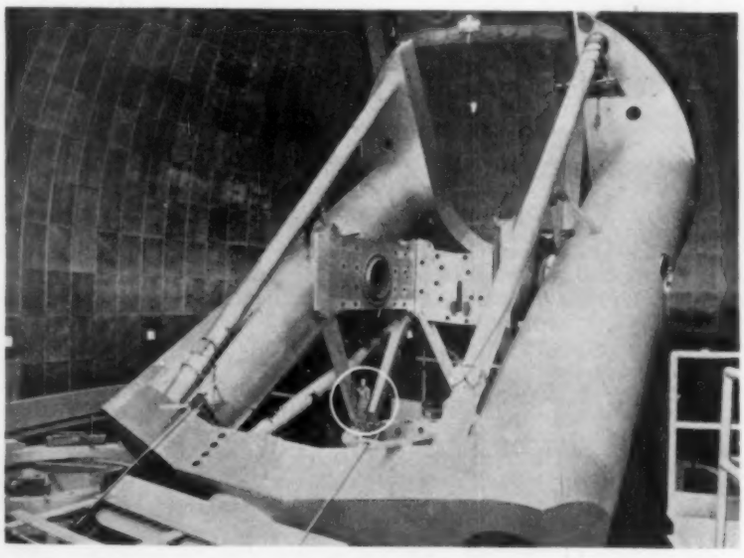


Fig. 9—Mt. Palomar Telescope Mount Showing Application of Tubular Members. (Courtesy of Capt. C. S. McDowell)

Under the cooling rates which prevailed in these welding tests the products of the transformation of the austenite in the high temperature heat-affected zone varied from sorbite to martensite, depending upon the composition (Fig. 14). This effect is also indicated by the response of the affected zone to etching in the macro-sections of Fig. 15. Increasing hardness and brittleness in the weld results with increasing carbon content, confirming the great hardening power of this element in comparison with manganese. Critical hardening resulted with carbon contents in excess of approximately 0.40 per cent with the steels of Series I, while such critical hardening was encountered in all steels of Series II due to their higher manganese contents, with the exception of the lowest carbon steel of the series. The relatively high hardness of the steels of these series may account for the inconsistency in the hardness values of their affected regions.

The relative weldability, therefore, declines with increasing carbon content, even though increasing carbon is accompanied by compensating reduction in manganese content. The generalization follows that for a steel of relatively high yield strength the increase in strength from the view-point of weldability is better obtained by compositions involving relatively low carbon and relatively high manganese content rather than the reverse.

Absolute weldability cannot be established by reason of the varying requirements for a weld with respect to ductility and toughness. If 20 per cent minimum elongation in the bend test or a maximum hardness of 250 to 275 Brinell is arbitrarily selected as an approximate requirement, the limiting composition would lie between (*a*) 0.33 per cent carbon and 0.90 per cent manganese, and (*b*) 0.41 per cent carbon and 0.73 per cent manganese for weldability under the welding deposition conditions of the tests.

Cooling rate of the weld metal and heat-affected zone from welding temperatures may be decreased by preheating and accentuated by precooling. It should, therefore, be possible to control the hardening resulting from welding by varying the temperature of the parent metal prior to welding—a condition only generally appreciated. Table III-A and III-B and Fig. 16 show the effect of preheating or precooling as applied to the $^1/_2$-in. thick plates. It is evident that for each steel there exists a critical temperature above which weldability is satisfactory and below which excessive hardening is experienced. A steel which is weldable at room temperature (I-C) is not weldable at lower temperatures (between 40 and 50° F.). A steel which is not weldable at normal temperature (I-D) possesses satisfactory weld ductility and toughness when preheated to a higher temperature (in this case between 110° and 150° F.). It is also apparent that as the sensitivity to welding at normal temperatures increases, higher preheating temperatures are required for successful welding. When great sensitivity is experienced at normal temperature steels may remain sensitive to cooling even though high preheat temperatures are applied, as evidenced by the data of steel I-G, and in such cases satisfactory weld properties can only be obtained by a slow and controlled cooling rate or by subsequent softening heat treatment. The effect of preheating in extending the heat-affected region and in reducing hardness in this region is observed in the macro-sections of Fig. 17. Great hardness was experienced in all steels when welded at temperature of 32° F. or lower, the heat-affected region generally displaying martensitic structures and microscopic cracks (Fig. 14-B).

How important and sharply defined this

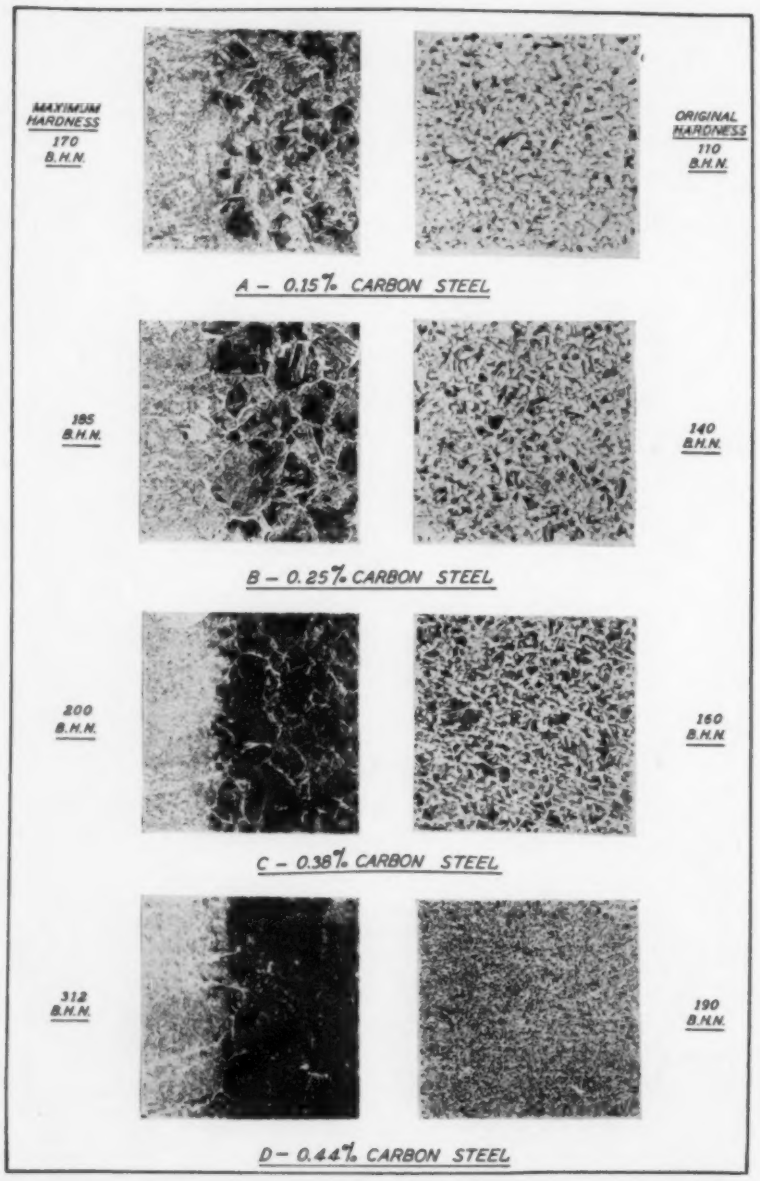


Fig. 10—Typical Microstructures and Hardness Values of the Original Parent Metal and Weld-Affected Zone of Carbon Steels

critical temperature is, was amply proved in the welding shop at Boulder Dam. It happened that production was begun in the late spring with shop temperatures above 90° F. When the first cold weather of the autumn arrived, cold meaning in this case 40 to 60° F., production that had been carried through without any trouble was stopped completely because of cracking and remained stopped until artificial heating was provided. The average analysis of the plate was carbon 0.30 to 0.035 per cent, manganese 0.75 to 0.85 per cent and silicon 0.15 to 0.20 per cent. This is roughly comparable with the somewhat lower carbon but higher manganese steel I-C, which in Table III shows critical sensitivity to welding between 40 and 50° F.

Since the thermal capacity of the $^1/_2$-in. thick experimental plate was relatively small the heat induced by actual welding appreciably increased the plate temperature and the cooling rate from welding temperature was not drastic (Fig. 13). Much faster cooling rates are encountered in the welding of most engineering structures where sizes or thicknesses of plates are generally greater. The effect of increasing section thickness on the hardening resulting from welding is shown in Table IV and Fig. 18, presenting comparative results on welds made on $^1/_2$-in. and $1^1/_2$-in. thick plates under identical welding conditions. The weldability in all cases has been seriously restricted by the increased thickness. In fact, negligible ductility and extreme hardness characterizes the $1^1/_2$-in. plate welds on all steels, with the possible exception of the lowest carbon steel of Series I. Aside from adversely affecting the physical characteristics of weld metal and the affected zone, increased thickness or rigidity of sections to be welded restricts weldability by reason of the internal stress condition subsequently discussed.

These experimental results indicate that three fundamental factors control for any welding technique the weldability of a steel (1) composition, (2) temperature of parent metal during welding and (3) its thickness. The last two factors affect the rate of cooling from welding temperature so that all these factors may be reduced to a single fundamental, namely, hardenability of the steel at various rates of cooling from temperatures greatly in excess of the critical range. Hardenability is used in its broadest sense, implying, in addition to hardness, decreased toughness or ductility.

It should be possible to establish a merit rating for the weldability of steels in terms of (1) composition or yield point, (2) critical temperature above which weld sensitivity is greatly reduced with corresponding improvements in weld properties (as measured by a suggested minimum elongation in the bend test of 20 per cent and hardness values of less than 250 Brinell in the weld-affected zone). Thus the relative weldabilities of steels I-C, I-D and I-F could be expressed as follows:

I-C	50,000	Y. P.	50° F.
I-D	50,000	Y. P.	150° F.
I-F	50,000	Y. P.	450° F.

Absolute weldability of the steels would necessitate the introduction of the third factor of thickness of sections to be welded.

Many variables in welding techniques will change the rate of cooling, and, therefore, become of importance in affecting the weldability of a steel. Cooling rates will be decreased by higher heat inputs, resulting from the use of larger electrodes, higher welding currents or slower travel speeds. These variables must be standardized or kept constant for any study of the relative weldability of different steels.

The comparative simplicity of the weld bend tests used in these experiments and the general uniformity of results on duplicate specimens suggest the desirability of its adoption along with hardness measurements of the weld-affected zone as a measure of the weldability of steels. While the weld quench test also indicates relative sensitivity to welding temperature, it has the disadvantage of being an artificial test, dependent upon the synthesizing by heat treatment of an impact test specimen the actual microstructure of the weld-affected zone. It has the further disadvantage of not being applicable to the testing of the important effects of preheating and parent metal thickness. Wide variations in the hardness of many of the weld quench test specimens were found. The advantage of a test based on actual welding effects is apparent.

There are other factors in steel quality aside from chemical composition which may influence weldability. Inherent or austenitic grain size has been suggested as an important variable with the fine-grained steels generally favored for welding, based on our knowledge of grain size effects on hardenability of steels in usual heat-treating practices. The majority of the experimental carbon-manganese steels were fine grained (Table I and Fig. 14-A), but two coarse-grained steels (1-B and 1-H) did not depart in their weldability-behavior from the behaviors of the fine-grained steels. It would seem that inherent grain size is of only minor importance in the weldability of steels.

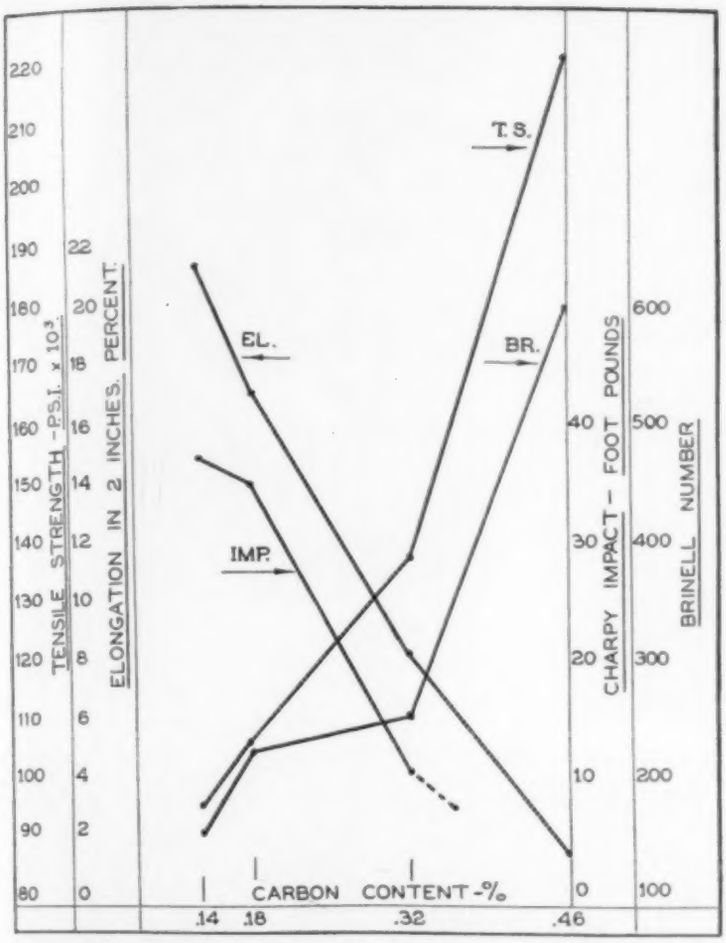


Fig. 11—Effect of Carbon Content on the Tensile and Impact Properties of Water-Quenched Steels (American Welding Society Handbook)

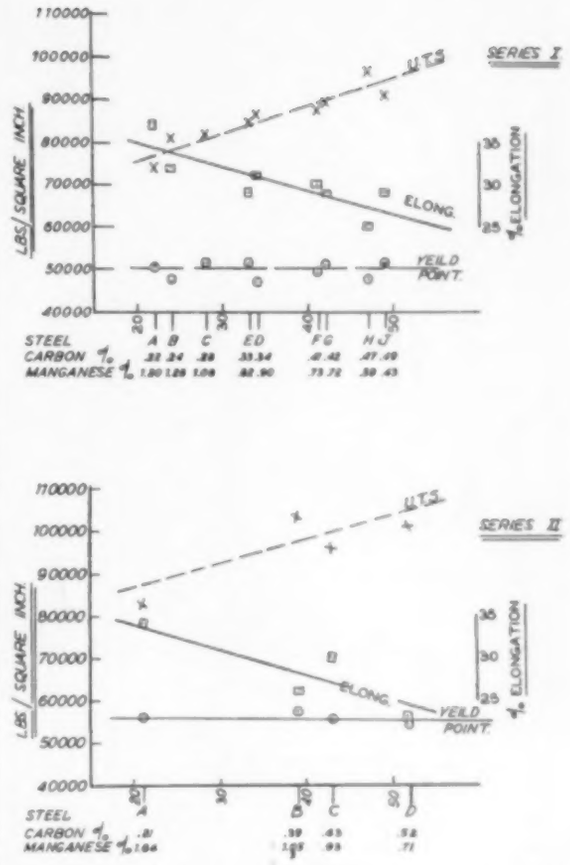


Fig. 12—Relationship between Tensile Properties and Chemical Analyses of Experimental Carbon-Manganese Steels

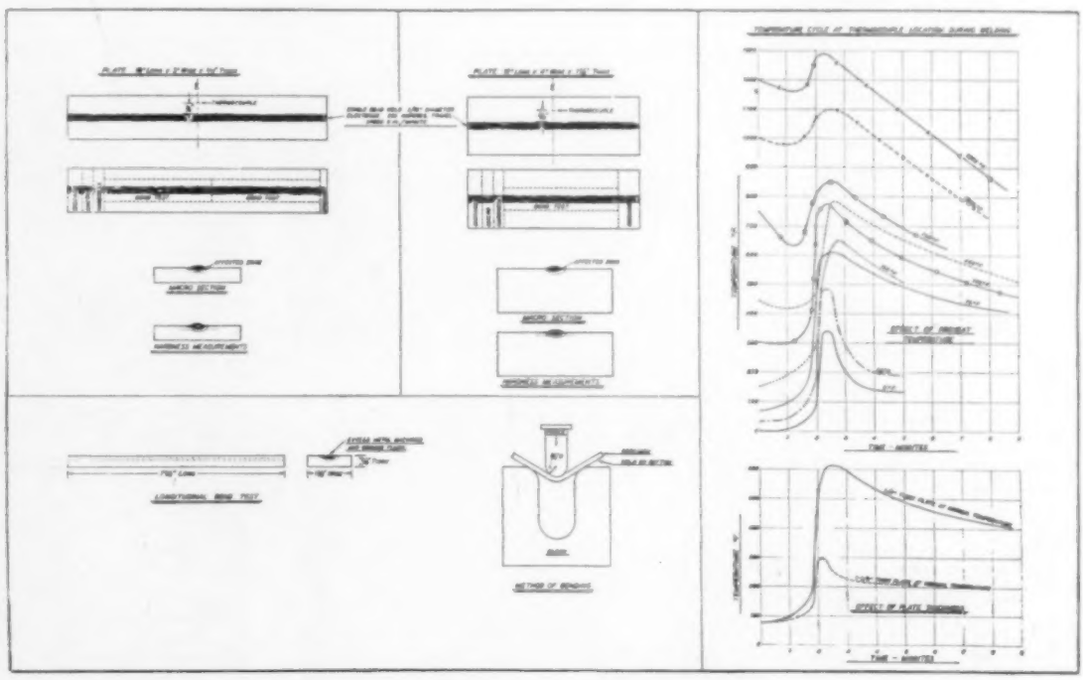


Fig. 13—Experimental Weld Tests Showing Types of Weld Tests and Heating of Plates Under Various Welding Conditions

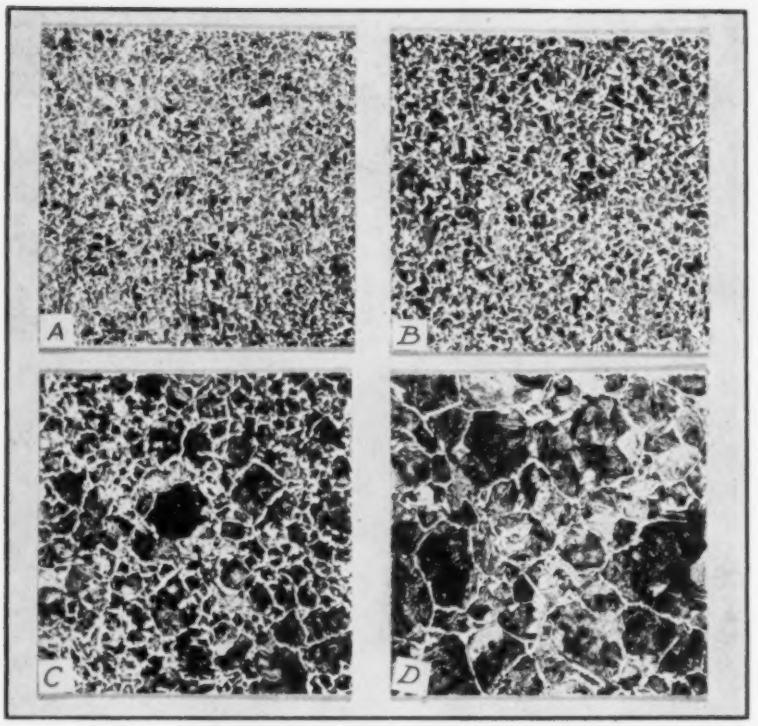


Fig. 14-A—Variation in Grain Size of Experimental Steels in Normalized Condition (Normalizing Temperature 1625° F.)

Some difficulties have been encountered due to variations in steel quality, arising from segregation. Figure 19 shows a panoramic view of the microstructure of a cracked weld. The crack in the weld metal originated in the fissure developed in a band of segregation in the parent plate. Such ghosts are apparently sensitive to welding temperature, shatter or fissure on welding, and act as a nucleus for the propagation of a shrinkage fracture into the weld metal. The sensitivity of banded plate to fissuring becomes greater as the heat input of the welding process increases and the elimination of this condition in the parent metal is extremely desirable for such welding processes.

Residual Stresses in Welded Structures.—The design of an engineering structure is predicated on the use of a maximum allowable working stress which will be produced within the unit elements of the structure by the application of external forces or service loads. Initial stresses are usually existent within the structure as a result of certain manufacturing and fabricating methods. Should these residual internal stresses lie in directions paralleling the stresses produced by the external load, so that the actual stress within the structural element may far exceed the design maximum allowable working stress. In those cases an appreciation of the intensity and extent of such stresses and of their effect upon the serviceability of the structure must be obtained.

The thermal conditions of fusion welding immediately suggest the production of high stresses within welded structures. The first external manifestation of the internally stressed condition of a welded structure lies in the distortion of the original shape of the tack-welded structure. For example, the bed plate of Fig. 20 decreased its length of 19 ft. approximately $^{5}/_{8}$ in. due to the contraction across transverse welds and along longitudinal welds.

The existence of such stresses is exhibited in a very elemental and forceful manner by the cracking which not infrequently occurs during welding. Such cracks may occur when the weld metal only partially fills the welding groove, when the shrinkage is concentrated within the narrow width of weld metal between the heavier adjoining parts, or after all welding has been completed and while the structure is cooling. These cracks are

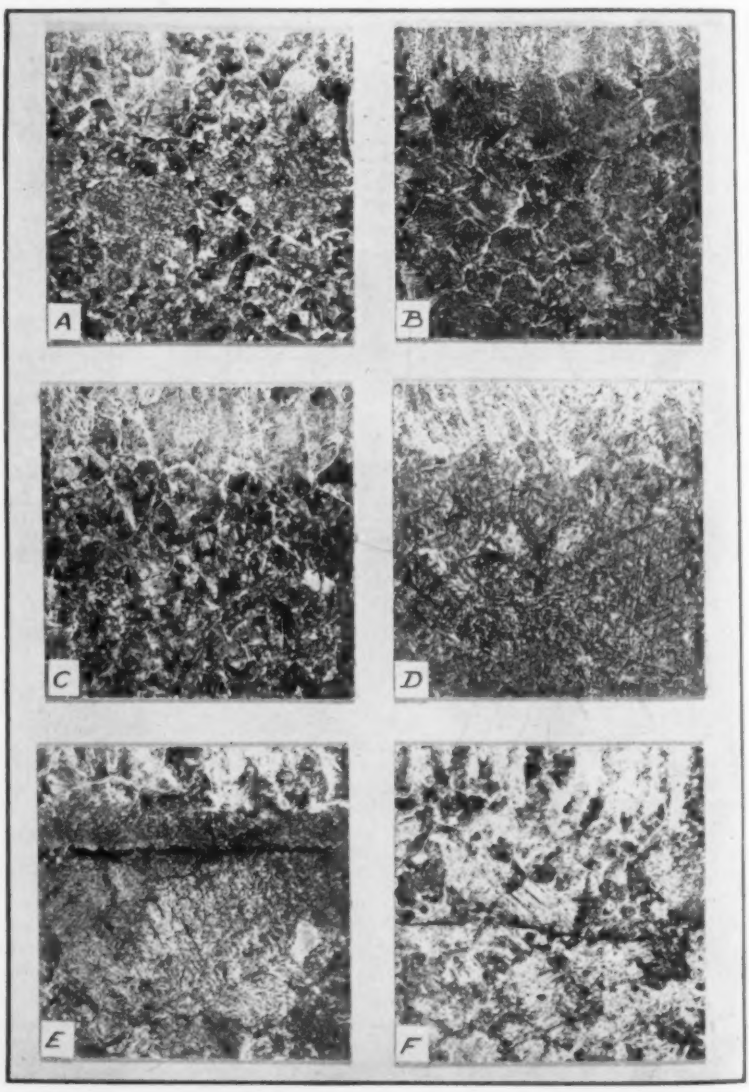


Fig. 14-B—Typical Microstructures of Fusion Zones of Experimental Steels, Showing Differences in Grain Size and Microstructural Phases

A—Steel I-H (C 0.47; Mn 0.59) Large grain—preheat temperature 75° F.; B—Steel I-B (C 0.24; Mn 1.28) Large grain—preheat temperature 75° F.; C—Steel I-F (C 0.41; Mn 1.73) Small grain—preheat temperature 75° F.; D—Steel II-B (C 0.39; Mn 1.05) Medium grain—preheat temperature 75° F.; E and F—Steel I-F (C 0.41; Mn 0.73) preheat temperature 0° F., showing microscopic cracks in troostitic-martensitic structure

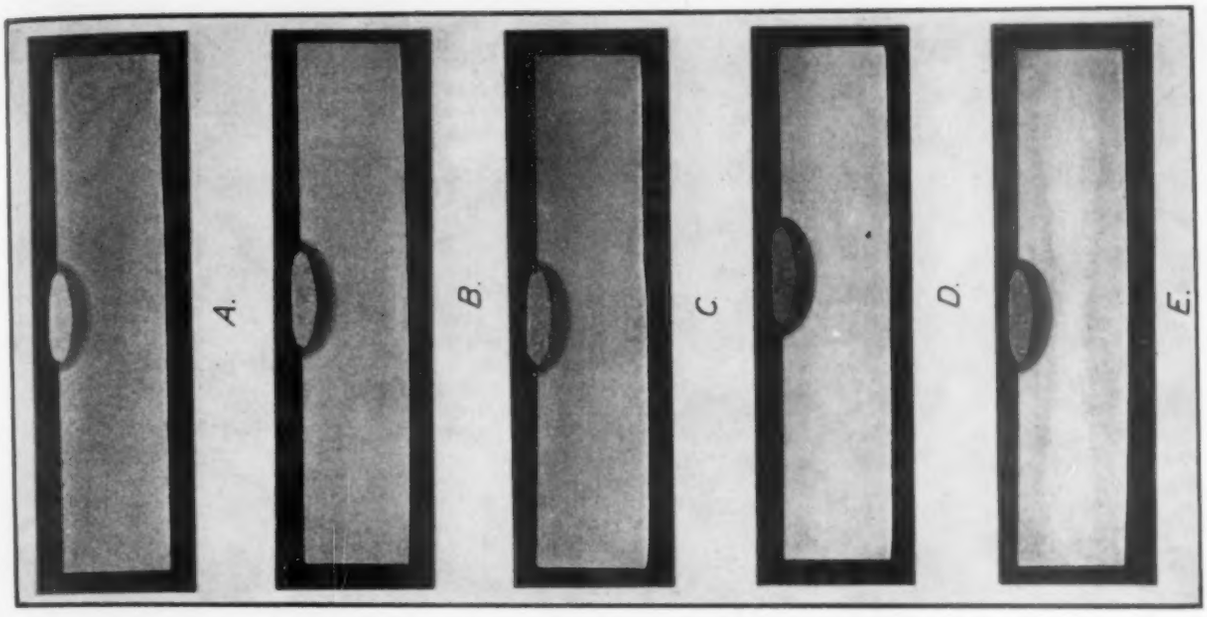


Fig. 15—Macro-Sections of Welds Showing Effect of Increasing Carbon in Parent Metal in Etched Affected Zones. Figures A to E Increase in Carbon from 0.22 to 0.52%

particularly frequent at temperatures below approximately 40 to 50° F. No appreciable distortion of the structure accompanies the cracking in spite of the fact that both weld metal and steel plate are relatively soft and ductile materials, this lack of appreciable deformation being due to the multi-directional character of the internal stress system.

The free contraction of weld metal is restrained by the colder base material, resulting in high tensional stresses in the weld metal and tensional and compressional stresses in the surrounding plate. If the plate material is relatively light, the yield point of the plate will be exceeded for some considerable distance from the weld, as evidenced by the Luder lines on the surface, these lines corresponding to the flaking off of the oxide scale along lines of maximum shear at or slightly above yield-point value. It is apparent that the plastically deformed zone must be bordered by plate material in an elastically stressed condition closely approaching yield-point value.

Residual welding stresses may be quantitatively measured by a number of different methods, the two most practical methods being as follows. First is the determination of the distortion of a pattern of strain-gage points, the pattern having been established on the surfaces of the parent metal plates prior to welding and measured before and after welding. Where the deformation is made up of both elastic strain and plastic flow as in the weld or region adjacent to the weld, such measurements cannot be directly translated into terms of stresses. At some distance from the weld where the yield point has not been exceeded and where plastic flow has, therefore, not occurred, the measurements may be translated into terms of stresses by use of the usual equations for two-dimensional elastic deformation. Stress and strain patterns may be plotted from explorations of this type as in Fig. 21.

The second method is determination of the elastic recovery of parts of a welded structure which are machined free from the structure, thereby largely releasing the locked-up stresses in the part removed. Several modifications of this latter method are available. The first is completely destructive and is only applicable to experimental work, the welded sample being cut up and the elastic recovery of the freed portions determined from strain-gage patterns established before cutting and measured before and after

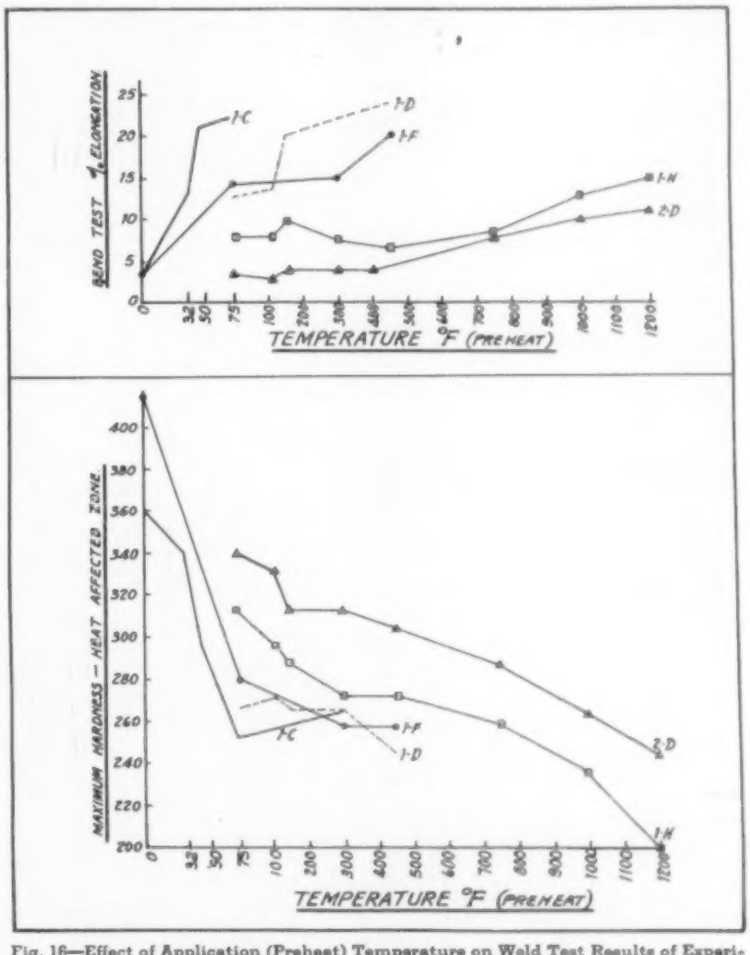


Fig. 16—Effect of Application (Preheat) Temperature on Weld Test Results of Experimental Steels

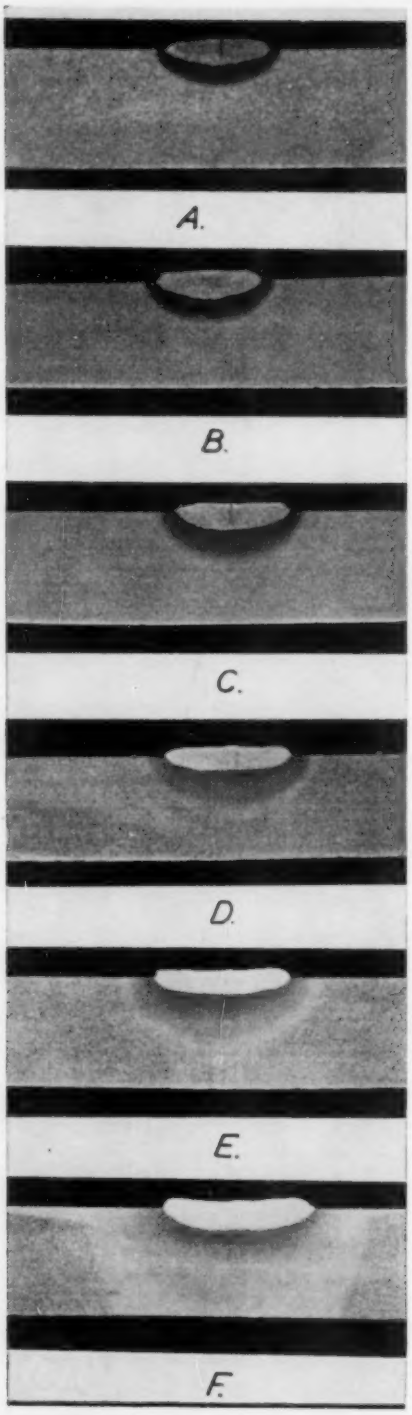


Fig. 17—Macro-Sections of Welds on Steel I-G Made Using Increasing Preheat Temperatures

A—75° F., B—150° F., C—450° F., D—750° F., E—1000° F., and F—1200° F.

cutting. The second modification is only partially destructive. In this method the elastic recovery of a plug trepanned from any portion of a structure is determined by measurements of strain-gage points before and after the trepanning operation (Fig. 29). In both modifications care in machining is necessary if alteration in the true strain pattern by the thermal and other machining stresses is to be avoided.

In any case the precision is not likely to be better than 2000 to 4000 lb. per sq. in.

No welding procedure exists whereby residual stresses may be eliminated or even appreciably diminished in magnitude unless it be a process of welding in which the parent metal is heated to plastic temperature prior to and during welding. The latter, however, is only a special case of thermal stress-relief accomplished simultaneously with the welding operation.

Certain welding procedures may, however, be advantageously employed to reduce the accumulation of strain and also reduce the extent of the metal with high residual elastic stresses. The ideal weld with respect to minimum strain should be one employing the minimum amount of deposited weld metal. The high-energy, short-time percussive resistance weld is in this respect ideal, but so far is limited to the welding of light sections. Fusion welding is so far limited to joint widths approximately one-third or more of the thickness of the plate. The effect of varying quantities of weld metal is illustrated by the results of tests on 1-in. plate, welded with grooves varying from $^1/_2$ in. to 1 in. in width (Fig. 22). The plates were free to move during welding and the distortion was measured by the contraction across the top of the joint and the rotation of the plates around the bottom of the joint. Multiple bead deposition was used, the weld metal being deposited from $^1/_4$-in. diameter electrodes and the effect of peening was eliminated. Total distortion increased with increasing amount of weld metal required, and as a corollary, had the plates been rigidly fixed, as in actual welded fabrication, the extent of the structure elastically stressed to high values would have correspondingly increased.

This series of tests also included a plate made by a single-pass, high-speed welding process (Fig. 23). The much smaller distortion found (Fig. 22), as compared with multiple bead deposition, is an important advantage which this welding process possesses in addition to its primary advantage of economy in weld metal deposition time. In this case minimum distortion results from the moderate gradients and more uniform temperature of the welded joint resulting from the high energy input of this process.

The extent of residually stressed material may be minimized by permitting free movement of the parts being welded in so far as possible without prohibitive

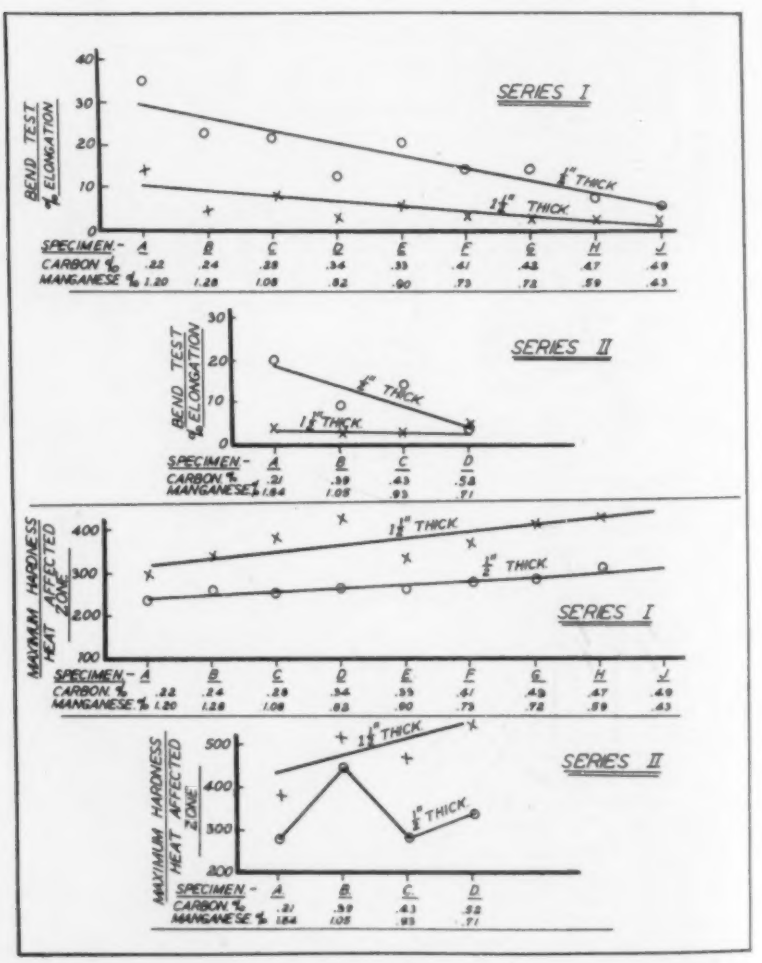

BEND TEST % ELONGATION
SERIES I
1" THICK
1½" THICK
SPECIMEN - A B C D E F G H J
CARBON % .22 .24 .28 .34 .35 .41 .43 .47 .49
MANGANESE % 1.20 1.28 1.08 .82 .90 .73 .72 .59 .43
SERIES II
1" THICK
1½" THICK
SPECIMEN - A B C D
CARBON % .21 .39 .43 .58
MANGANESE % 1.84 1.08 .93 .71
MAXIMUM HARDNESS HEAT AFFECTED ZONE
SERIES I
1½" THICK
1" THICK
SERIES II
1½" THICK
1" THICK

Fig. 18—Effect of Thickness of Parent Metal—$^1/_2$ In. *vs.* $1^1/_2$ In.—on Weld Test Results of Experimental Steels

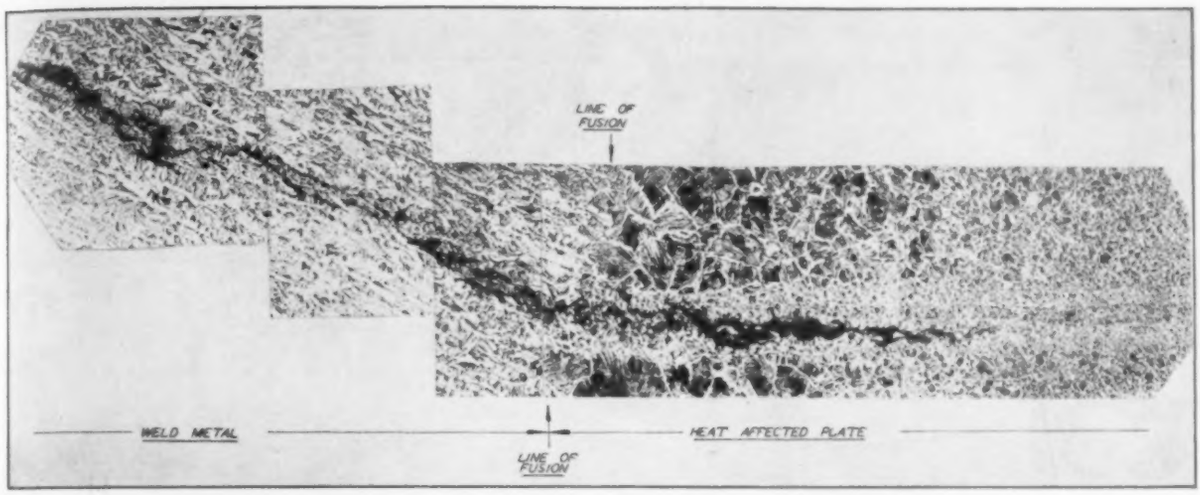


Fig. 19—Panoramic View of Microstructure of Fusion Zone of Cracked Weld, Due to Segregated Zone in Plate Material

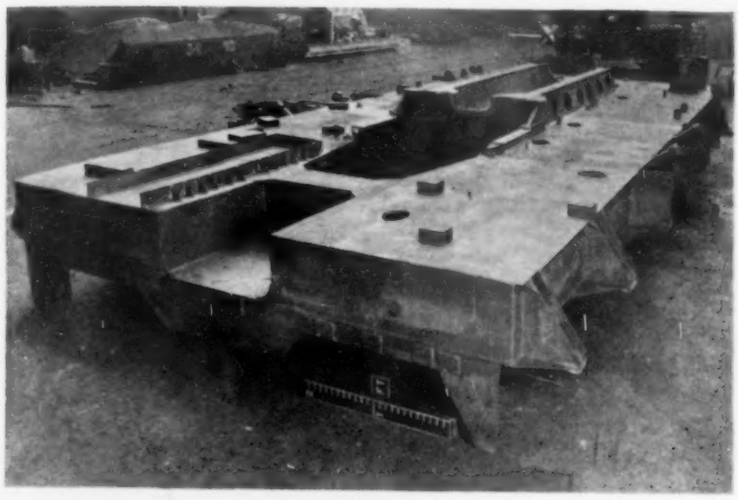


Fig. 20—Diesel Engine Bed Plate

distortion of the structure. Negligible distortion of the structure can only be attained by holding the structure rigid, preventing relative freedom of movement, and this can only be attained at the expense of placing greater areas of the structure under high internal stress. Figure 24 shows an experiment in which a circumferential joint was made between two pipes rigidly held at their ends by a heavy internal restraint to prevent free contraction endwise. The contraction of the weld region resulted in high tensional stresses of approximately 16,000 lb. per sq. in., through a distance of 12 ft. from the weld. This example of rigidity of structure, leaving wide areas in a state of high residual stress, is extreme; however, a case of this exact type was actually encountered in large pipe construction. Such conditions occur in most structures welded in heavy jigs to avoid distortion.

The effect of residual stresses upon the serviceability of welded structures is not as well defined as our present knowledge of their magnitude and distribution. Unfortunately, experimental procedures for the determination of their effects under varying service conditions are in general lacking. This is due to the difficulty involved in correlating results of even large laboratory models with the possible behavior of prototypes that are usually much larger. The importance of residual stresses may be best appreciated by recitation of certain experiences involving the comparative behavior of stress-relieved and unstress-relieved structures under static and shock loading.

In the construction of the Boulder Dam penstocks, Fig. 25 shows a pipe section 30 ft. in diameter which was accidentally dropped through a distance of 15 in. during manufacture and before being stress-relieved. A fracture developed from the top of the section at a location approximately 180° from the impact point on bottom. This fracture ran through the end buttstrap and the weld attaching it for a length of about 8 ft. into the $2^{1}/_{16}$-in. thick pipe wall. A second smaller fracture developed through the reinforcing band at the bottom section.

As another example, Fig. 26 shows a 30-ft. diameter support and stiffener ring which fractured into six pieces when in the as-welded condition it was being raised to a vertical position. This ring weighed 37,000 pounds and computations showed that the maximum bending stress in the

TABLE IV

EFFECT OF THICKNESS ON WELDABILITY OF CARBON-MANGANESE STEELS

Steel Designation	% Elongation of Outer Fibres of Bend Test Specimens								
	I-A	I-B	I-C	I-D	I-E	I-F	I-G	I-H	I-J
½" Thick	36	21	21	13	17	16	15	8	7
	34	26	23	13	25	13	15	8	6
1½" Thick	14	5	8	3	6	4	3	3	3

Steel Designation	II-A	II-B	II-C	II-D
½" Thick	24	9	18	3
	16	9	11	4
1½" Thick	4	3	3	5

Steel Designation	Maximum Brinell Hardness of Heat-Affected Zone								
	I-A	I-B	I-C	I-D	I-E	I-F	I-G	I-H	I-J
½" Thick	240	260	252	265	265	280	288	313	313
1½" Thick	300	340	381	436	340	370	414	436	447

Steel Designation	II-A	II-B	II-C	II-D
½" Thick	280	447	280	340
1½" Thick	381	518	470	542

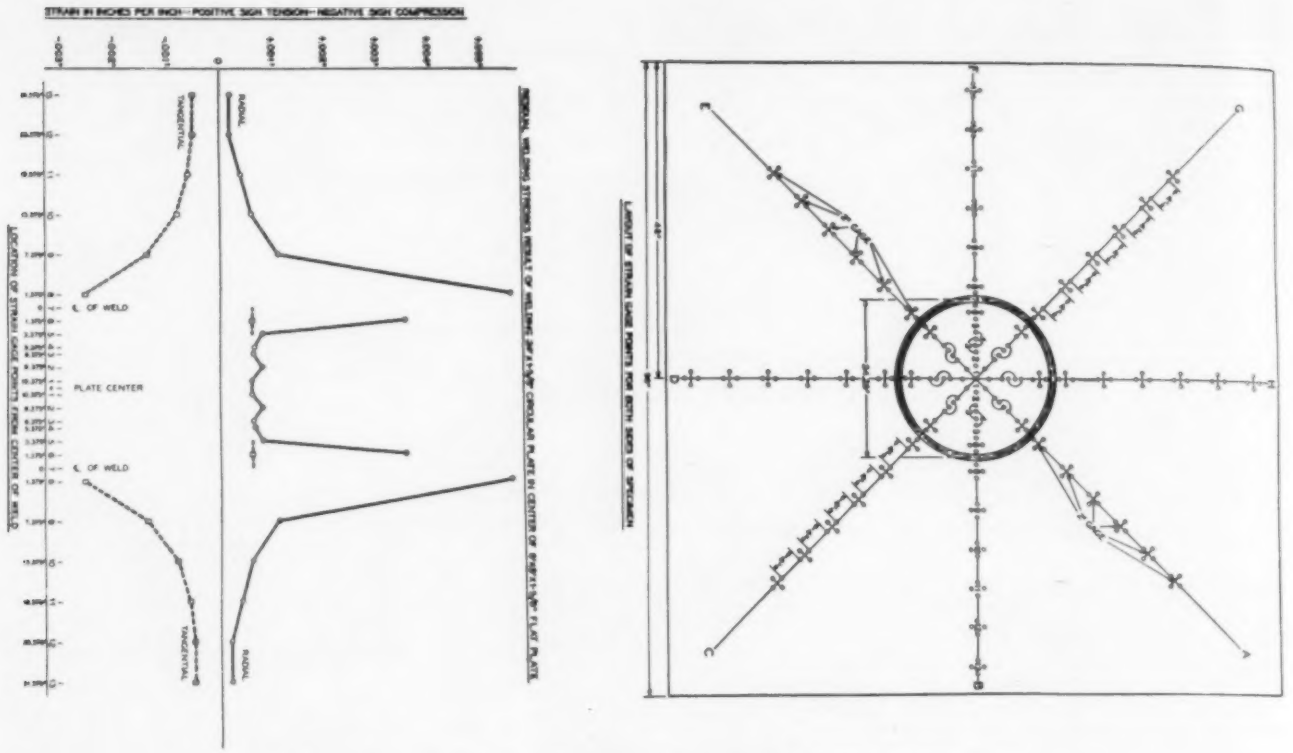


Fig. 21—Strain Pattern on Plate Surfaces Resulting from Welding Rigid Circular Joint in Center of Large Plate

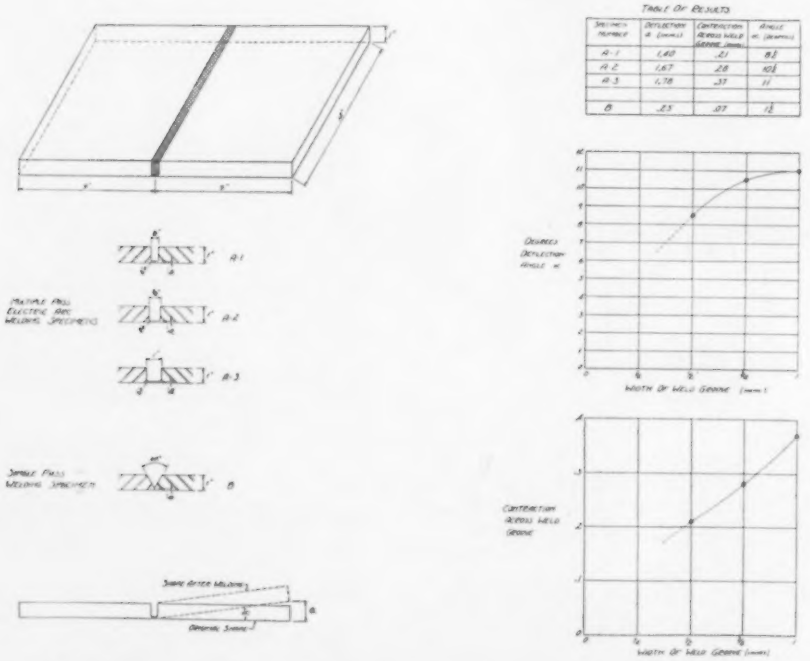


Fig. 22—Effect of Variables in Technique on Total Deformation Resulting from Welding. (Varying Width of Groove and Single-Pass vs. Multiple-Bead Deposition)

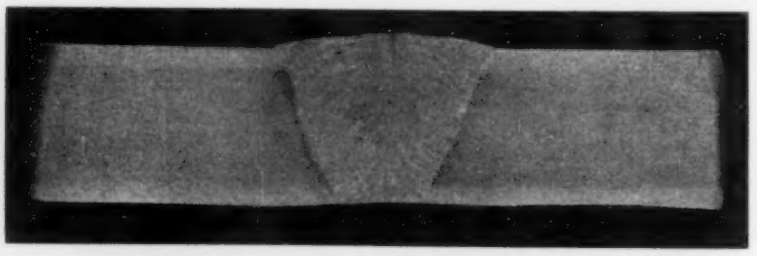


Fig. 23—Macrostructure of Section of Single-Pass Weld

ring as it was raised was only 6550 lb. per sq. in.; yet the addition of this relatively low, slowly applied stress to the initial stress resulting from welding was sufficient to cause the fracturing. Compared with these two cases, Fig. 27 shows another pipe section similar to the first, excepting that it had been stress-relieved before it was dropped. It fell several feet and was badly distorted as the figure shows. In spite of the severe deformation of the structure, no cracks were developed, all the energy being absorbed by the deformation.

The effect of residual welding stresses on accelerated corrosion has been observed in oil refinery vessels where supports have been welded in the field to the outside of the vessels and where after several months of operation a pattern of the external unstress-relieved support welds was etched on the inside surface of the vessels. Caustic embrittlement has also been observed around unstress-relieved welds of certain pressure vessels exposed to strong caustic soda solutions, the stress factor in the caustic embrittlement failure being contributed by the residual stress condition.

There are, of course, numberless welded structures which have not failed in service under widely varying conditions without benefit of stress-relieving treatment. The necessity for stress-relief increases as the rigidity of the structure increases. For each type of structure stress-relieving will become advisable or necessary when the thickness of the parts or the amount of welding exceeds some limiting magnitude. No fixed limits are likely to be established. The following discussion may, however, assist in considering the nature and effect of residual welding stresses as related to mass or size of welded structures.

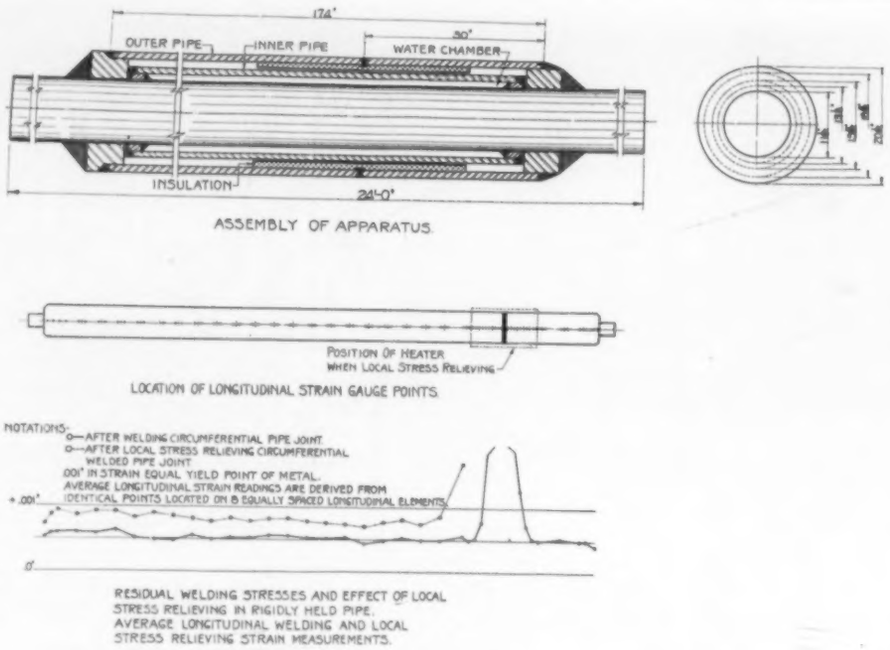

174"
OUTER PIPE
INNER PIPE
30"
WATER CHAMBER
INSULATION
24'-0"
ASSEMBLY OF APPARATUS
POSITION OF HEATER WHEN LOCAL STRESS RELIEVING
LOCATION OF LONGITUDINAL STRAIN GAUGE POINTS
NOTATIONS:-
O—AFTER WELDING CIRCUMFERENTIAL PIPE JOINT.
O—AFTER LOCAL STRESS RELIEVING CIRCUMFERENTIAL WELDED PIPE JOINT.
.001" IN STRAIN EQUAL YIELD POINT OF METAL.
AVERAGE LONGITUDINAL STRAIN READINGS ARE DERIVED FROM IDENTICAL POINTS LOCATED ON 8 EQUALLY SPACED LONGITUDINAL ELEMENTS.
+.001"
0"
RESIDUAL WELDING STRESSES AND EFFECT OF LOCAL STRESS RELIEVING IN RIGIDLY HELD PIPE.
AVERAGE LONGITUDINAL WELDING AND LOCAL STRESS RELIEVING STRAIN MEASUREMENTS.

Fig. 24—Experimental Assembly to Show Effect of End Restraint on Residual Welding Stresses and Stresses Due to Locally Stress-Relieving of a Girth Joint in a Pipe

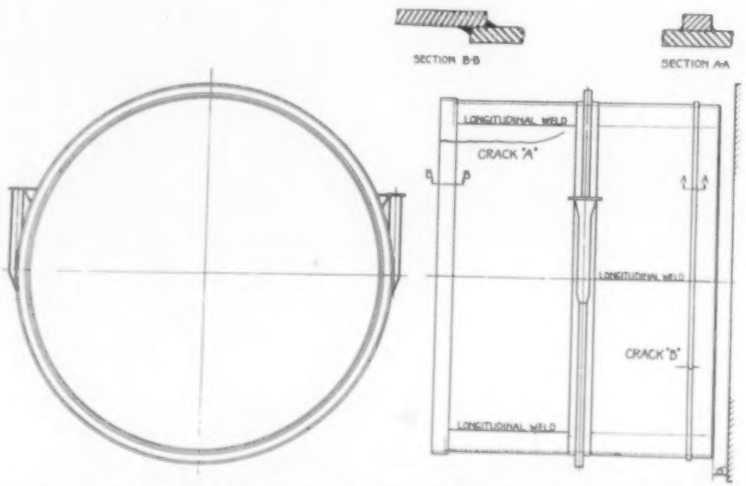


Fig. 25—30 Ft. Diameter Unstress-Relieved Pipe Section Showing Cracks Developed as a Result of Section Dropping Through 15 In. Height

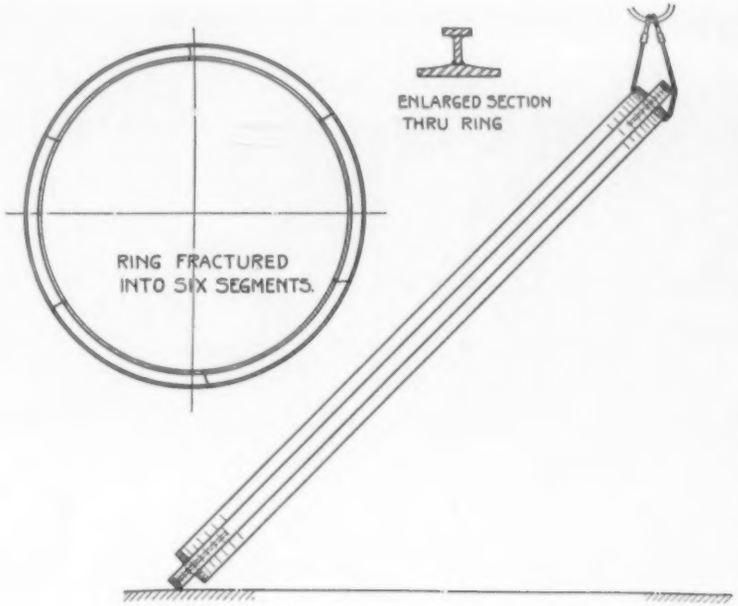


Fig. 26—Unstress-Relieved Stiffener and Support Ring Fractured During Handling

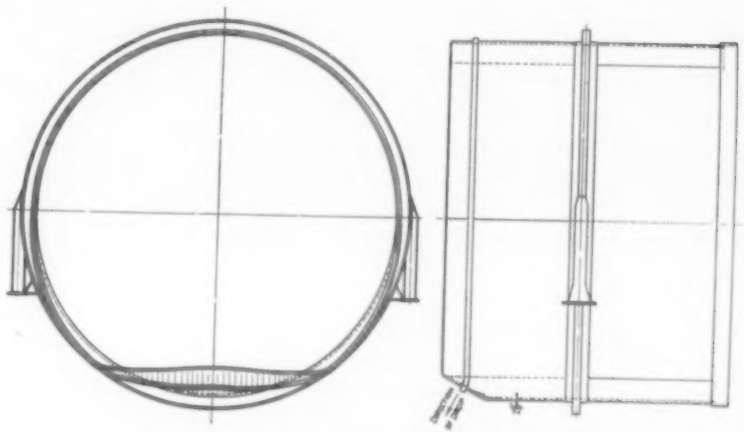


Fig. 27—30 Ft. Diameter Stress-Relieved Pipe Section Showing Severe Deformation Without Cracking

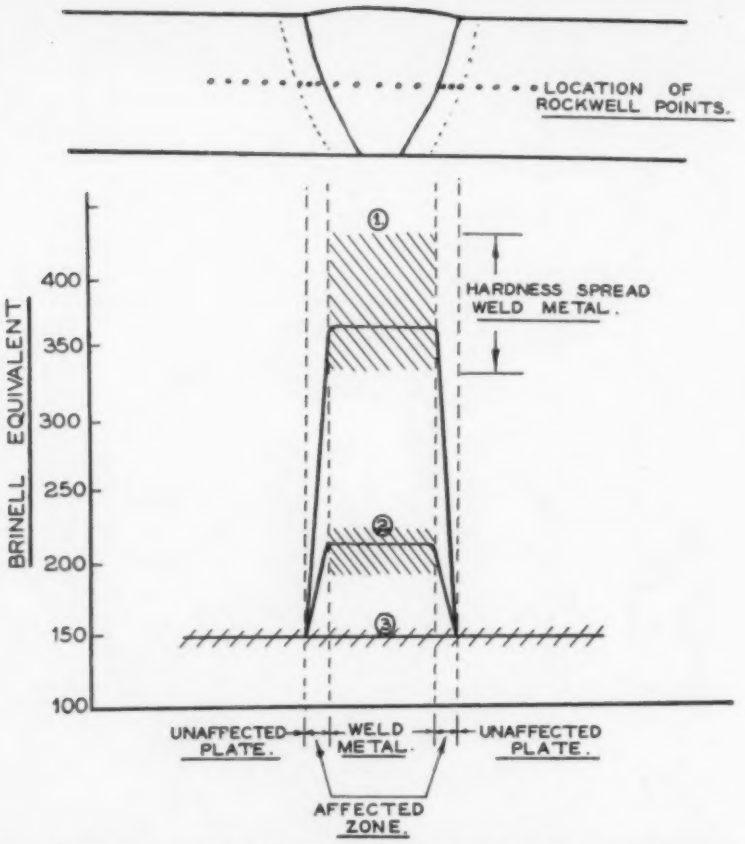


Fig. 28—Hardness of 4-6% Cr—1/2% Mo Weld (1) As-Welded, (2) Stress-Relieved, (3) Annealed

Each specimen, structural unit or welded assembly in a stress-free condition can withstand on application of external loading a definite degree of deformation prior to failure. Maximum deformation is secured under uni-axial loading, as in a small tension specimen of limited cross section. The introduction of a second stress at right angles to the original stress naturally reduces the ultimate plasticity of the specimen or structural unit. One investigator reports a reduction of 75 to 80 per cent in ductility at rupture when the second equal tension is introduced, although this amount of reduction has not yet been independently confirmed. It is to be expected also that with the introduction of a third normal equal stress the ductility at rupture will be further reduced. As thickness of a structural section increases, the ultimate plasticity is reduced by reason of inability of one portion of the section to feed metal to another. For example, plates 2 in. in thickness may be safely cold-bent to the usual diameter of pressure vessels, whereas much heavier plates, say 5 in. in thickness would undoubtedly be fractured.

It is apparent that the strains established by welding will detract from the ultimate plasticity which may be developed by any particular welded unit and that the residual multi-directional stresses must reduce the ultimate plasticity of an unstress-relieved unit. These welding effects are of minor importance in welded units of relatively thin plates or shapes where freedom to deform plastically without fracture is not limited to any great degree. These welding effects become increasingly greater as section thicknesses of the welded structure increase and the unit per se is restricted in its capacity to deform plastically. A certain thickness must necessarily be reached for any structure which in the as-welded condition will have negligible ability to further deform plastically by reason of flow which has already occurred during welding, together with the high multi-directional residual elastic stresses. When such a condition arises the application of an external load, particularly a shock load, is likely to cause failure.

For reasons such as these it is considered necessary to eliminate or reduce the reduce the residual internal stresses of many welded structures, this being generally accomplished by thermal treatment in the plastic temperature range. With increasing temperature the yield point of steel increases, reaching relatively low values for temperatures in excess of 1000° F. When a welded structure is heated to temperatures of this order, the initially higher internal stresses produce a plastic flow and are thereby reduced to a value approximating the high temperature yield point. For the usually employed stress-

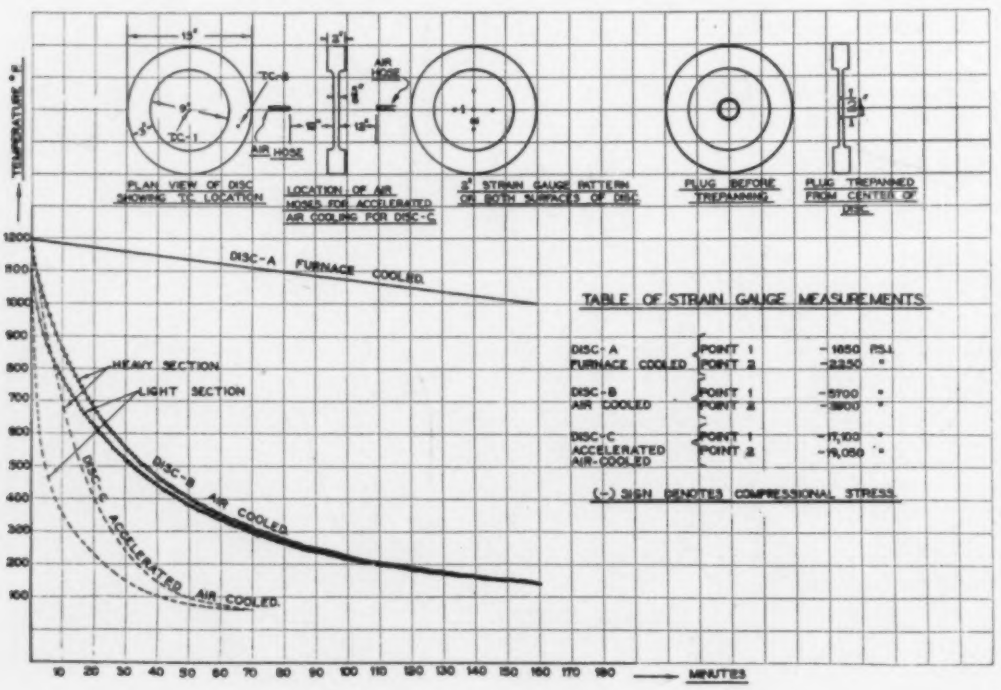
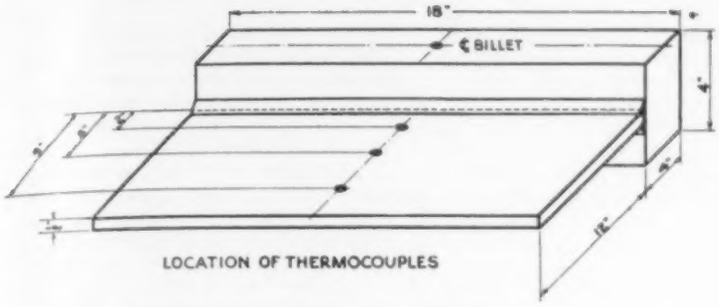
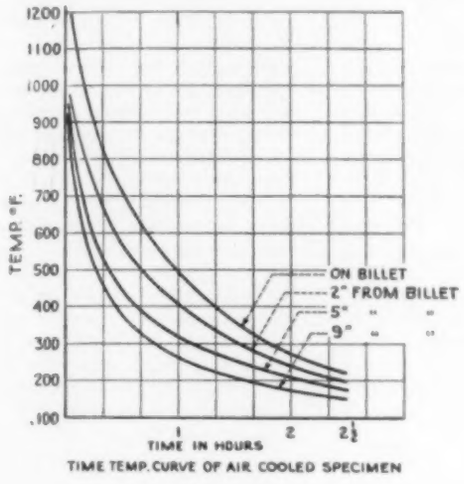
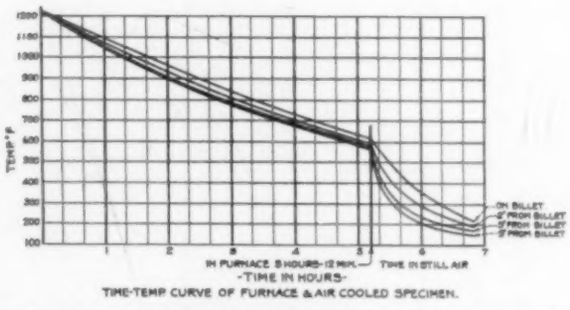

TEMPERATURE °F.
PLAN VIEW OF DISC SHOWING TC. LOCATION
LOCATION OF AIR HOSES FOR ACCELERATED AIR COOLING FOR DISC-C
3" STRAIN GAUGE PATTERN ON BOTH SURFACES OF DISC
PLUG BEFORE TREPANNING
PLUG TREPANNED FROM CENTER OF DISC
DISC-A FURNACE COOLED
HEAVY SECTION
LIGHT SECTION
DISC-B AIR COOLED
DISC-C ACCELERATED AIR COOLED
TABLE OF STRAIN GAUGE MEASUREMENTS
DISC-A FURNACE COOLED POINT 1 -1650 PSI.
POINT 2 -2250 "
DISC-B AIR COOLED POINT 1 -5700 "
POINT 2 -3800 "
DISC-C ACCELERATED AIR-COOLED POINT 1 -17,100 "
POINT 2 -19,050 "
(-) SIGN DENOTES COMPRESSIONAL STRESS
MINUTES

Fig. 29—Experimental Steel Disks Showing Temperature Differentials and Stresses for Different Rates of Cooling



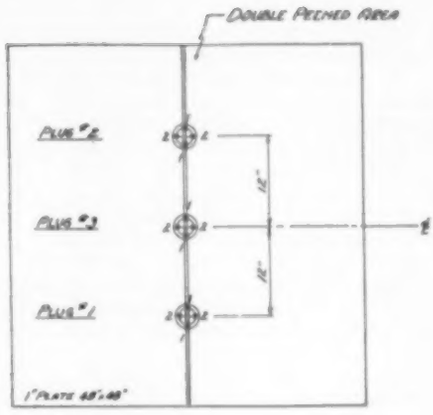


TIME TEMP. CURVE OF AIR COOLED SPECIMEN



TIME-TEMP CURVE OF FURNACE & AIR COOLED SPECIMEN.

Fig. 30—Steel Test Specimen Showing Temperature Differentials Arising from Different Rates of Cooling



LOCATION OF PLUGS ON WELD

TABLE OF RESULTS

LOCATION POINT NO	OPERATION #1	OPERATION #2	OPERATION #3
PLUG #1			
1-1	+ 32,550		
2-2	+ 277		
PLUG #2			
1-1		- 38,275	-15,970
2-2		+ 9,580	-11,545
PLUG #3			
1-1			+ 11,670
2-2			+ 3,859

NOTE
4" x 8" x 1" PLATE - LONGITUDINAL SEAM HOT STRESS RELIEVED BY HEATING - PLATE A-2 - TEST #3
OPERATION 1 - WELD MADE AND PLUG TREPANNED
ELASTIC RECOVERY CORRESPONDING TO RESIDUAL STRESS
OPERATION 2 - WELD AREA DOUBLE PEENED LEAVING UNPEENED ISLAND AROUND PLUG 2. CHANGE IN STRESS DUE TO DOUBLE PEENING
OPERATION 3 - PLUGS 2 AND 3 TREPANNED
ELASTIC RECOVERY CORRESPONDING TO FINAL RESIDUAL STRESS.

Fig. 31—Test Plate Showing How Residual Welding Stresses May Be Changed by a Mechanical Method. (Double Peening)

relieving temperatures of 1100 to 1200° F., the yield point of plain carbon steel will vary from about 5000 to 2000 lb. per sq. in., so that the final residual stress is of this magnitude. The yielding at stress-relieving temperature is also influenced by time and by the rigidity of the structure. The length of time for efficient relief will, therefore, depend upon (*a*) the temperature employed, (*b*) the thickness, (*c*) the rigidity of the sections and (*d*) the resistance of the steel to yielding at the selected temperature. Holding time of one hour per inch of thickness of maximum section involved is typical of present practice for plain carbon steels.

Full annealing of a welded structure at temperatures above the critical range would completely eliminate all residual stresses and at the same time beneficially change the microstructure of the welded joint. While this practice has been adopted in certain European countries for the stress-relieving of welded pressure vessels, it is rarely applied in this country for welded structures of plain carbon steels, since it is considered that stress-relief for most purposes is accomplished at lower temperatures and the dangers of distortion and excessive scaling are minimized. Full annealing is only resorted to in the case of sluggish alloy steels (Fig. 28).

The rate of heating and cooling in the stress-relieving cycle is of importance, particularly the cooling rate where sections of unequal thickness constitute the structure being stress-relieved. Temperature differentials of the order of 150° F. between different parts as cooling below 700° F. proceeds may re-establish internal stresses of high magnitude. This may be illustrated by the simple experiments of Fig. 29, in which three disks were first fully annealed and subsequently reheated to 1200° F. as for stress-relieving. The disks, however, were cooled from stress-relieving temperature at different rates: A—furnace-cooled, B—air-cooled and C—accelerated air-cooled by an air blast. The furnace cooling of disk "A" was at a slow rate, and, therefore, both thin and thick sections cooled at almost the same rate. In the case of air-cooled disks, both "B" and "C," a differential in temperature during cooling was established between heavy and light sections. These differentials produced a compressional stress in the thin section, the magnitude being measured by the elastic recovery of plugs trepanned from the centers of the disks. Figure 30 shows a similar effect on an experimental welded assembly, involving sections of more unequal thickness and less symmetry.

It is evident that rates of cooling in ex-

cess of a certain amount will result in the re-establishment of an internally stressed condition in structures involving sections of unequal thickness. Present practice in the stress-relieving of pressure vessels employs a cooling rate of 400 to 500° F. per hour, divided by the plate thickness in inches. It would seem from the experimental results that this practice is conservative for the average structure. For intricate structures which do not provide free access of furnace atmosphere to all parts, or which may require machining to exact tolerances, smaller rates of cooling down to normal temperatures may be advisable.

In many cases it is impractical to stress-relieve a welded structure by heat-treating as a unit. In some cases parts of the structure may be satisfactorily stress-relieved by local heat treatment, as, for example, girth welds in steam piping. The practicability of local treatment of a particular structure must be carefully considered. The success of the method depends upon the establishment of a low thermal gradient and it is questionable whether those obtained in practice are sufficiently low. The locally heated metal is generally restrained from expanding freely by the colder surrounding material. Upsetting in the plastic range, therefore, occurs with the re-establishment of stresses and distortion when the structure cools. The local heating, however, does redistribute the stress with an accompanying improvement in the mechanical properties of the welded joint.

Care should be exercised in the local heating of any pipe joint that the pipe is free to expand and contract longitudinally; otherwise high longitudinal tensional stresses may be established along the entire pipe length between rigidly fixed points. For example, local stress-relieving of the girth joint of the rigidly fixed pipe, previously referred to (Fig. 24), resulted in longitudinal stresses approximately twice as great as the original residual welding stresses.

Effective stress-relief of welded structures may also be attained by cold-working of the structure at selected locations. The required dimensional changes for relief of stress are very small. The method may be best illustrated by the experiment of Fig. 31, in which a weld has been made in the center of a plate. The weld area is in a state of tensional stress in both transverse and longitudinal directions and if unrestrained would assume shorter dimensions. Relief of the stress within the weld may be accomplished by plastically elongating the weld. This was actually accomplished by double peening the weld area by heavy hammers, simultaneously striking surfaces.

A very practical application of mechanical stress-relief lies in the elimination of the stressed condition in the plate surrounding welded tubes in boiler drums by subsequent rolling or expanding (Fig. 32).

In all cases of mechanical stress-relief, knowledge of the pattern of the residual welding stresses is necessary so that cold-working may be applied in the proper directions and locations. Excessive plastic deformation by cold-working will result in the establishment of new stress patterns. In important structures it should only be done with accompanying strain-gage measurements of the movements resulting from cold-working or by applying a degree of cold-working predetermined by experiment on similar structures involving exploration by strain-gage measurements.

Summary

The advantages of welded construction as contrasted with other types have been illustrated by a number of examples of important engineering structures. The discussion has included important limitations of welded construction, arising from fundamental conditions pertaining to the welding art. Many problems for the removal of these limitations remain. Some of these are as follows:

Further study of unit shapes and in particular of their junctions for structural uses is desirable if the low stress gradients made possible by welding are to be utilized to the greatest advantage. Study must be given to the conditions under which the disadvantages of field welding can be minimized by changes of technique and improvements in the design type of field welds. Where difficulties in field welding cannot be overcome, study must be directed toward breaking up the total design into unitary parts best adapted for completion in the shop with stress-relieving, if necessary, and subsequent assembly in the field by bolting or riveting.

The welding behavior of plain carbon steels of limited carbon content has been on the average very satisfactory. Some occasional difficulties have been encountered due to irregularities in steel quality. Laminations become serious if superimposed welds produce stresses normal to the lamination. Banding and other types of defects associated with non-metallic segregations will be increasingly more serious as larger and larger energy inputs are used in welding. Improvements in these respects are contributions in the art to be made by the steel maker rather than the welder.

While the weldability of steels with respect to composition is generally understood, exact knowledge is lacking, especially when the steel contains more than normal amounts of an additive alloying element, as, for example, manganese. Experimental work in quantity will be necessary before limiting compositions with respect to weldability under various techniques can be definitely established.

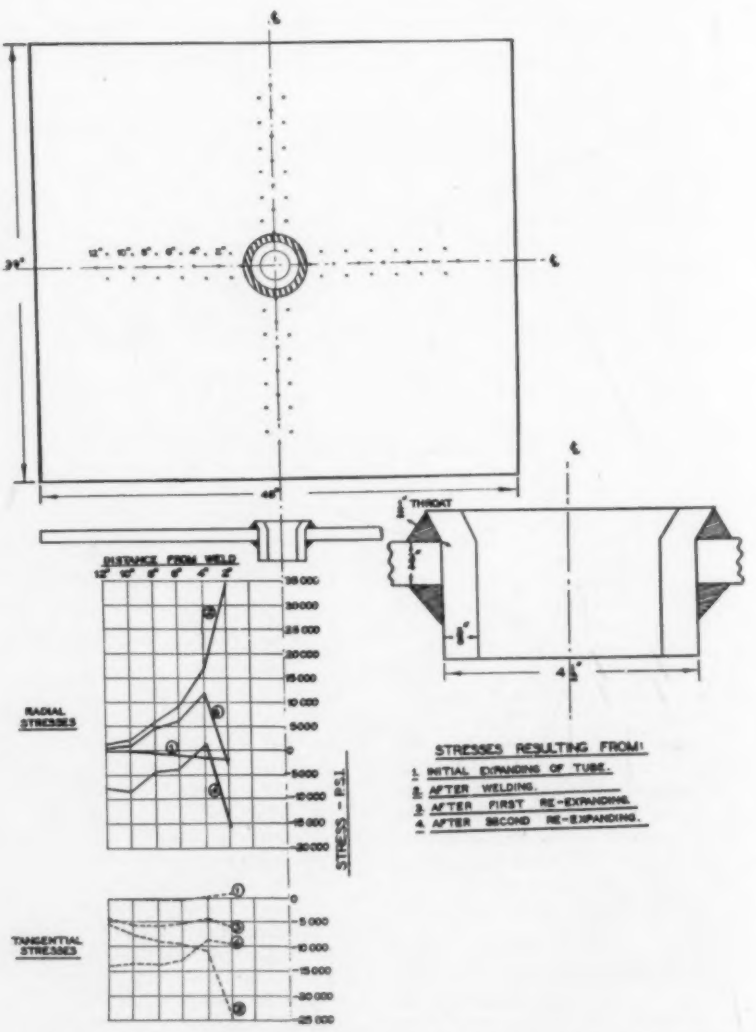


Fig. 32—Test Specimen Showing How Residual Welding Stresses May Be Changed by Expanding Tube with Roller-Type Expander

Simple tests necessary for economical exploration of this experimental field are now in process of formation although no standards have as yet been adopted. The most likely tests involve a study of the heat-affected zone of the parent metal resulting from deposition of a single bead of weld metal under controlled conditions. The bend tests of such weld specimens, together with determinations of the maximum weld hardness, appear to be the simplest and best criteria.

The practical advantages of preheating in overcoming cracking difficulties in welding steels of limited weldability are generally recognized and appreciated. Experimental results seem to indicate that for any steel there exists a critical narrow band of temperature below which sensitivity to welding temperature is marked and above which cracking difficulties are rapidly improved. For ordinary structural carbon steels this temperature lies in the neighborhood of 40–50° F. As the hardenability of a steel increases, this critical temperature becomes progressively higher. Enough experimental work should be undertaken to establish for each composition this limiting preheat temperature. Experimental results seem to indicate that in making a weld the heat induced in the parent metal by welding operations is far less important than actual application temperature at which the weld is made. With sufficient experimental data available it should be possible to establish a merit rating for the weldability of steel, constituted of (1) the chemical composition or yield point and (2) the critical temperature as it has been referred to above.

Section thickness or rigidity of structure to be welded is a necessary item in the consideration of the absolute weldability of a steel. It is one of the most important factors for determining when stress-relieving is or is not necessary or when local stress-relieving may be permissible, and, therefore, warrants an extended study.

To reduce difficulties from distortion, welding should be viewed in the light of minimizing the total quantity of added fusion metal and of effecting a weld through the entire section of the joint as simultaneously as possible. This has been at least partially realized in the single-pass welding process, which, coupled with its high deposition speeds, possesses the advantage of low total distortion and moderate thermal gradients in cooling.

The problem of the necessity of complete unit stress-relieving of welded structures and the associated problem of the conditions under which local stress-relieving may be permissible may never have definite answers. Numerous factors such as material, technique, size, rigidity and intended usage constitute a system so complicated that the present state of our knowledge cannot be expected to fix logically exact limits. Until by experimentation and by accumulation of experience much more is known of the effects of these factors a conservative view-point is warranted in both cases. The existing rules applying to complete stress-relieving appear to be much more conservative than the rules for local stress-relieving when the latter are applied to large and thick structures.

With the solutions of these problems we may venture to predict advance in the welding art along the following lines: (1) much higher welding speeds; (2) marked reduction in the volume of weld metal required in a welded joint, with a resultant minimizing of distortion and extent of the stress affected area; (3) the more general use of preheating and controlled cooling, permitting the use of higher strength steels; (4) the further development of steels possessing the optimum composition for strength and ready weldability.

A. S. M. E. BOILER CODE

Use of Stainless Steels in Unfired Pressure Vessels

A SPECIAL subcommittee of the Boiler Code Committee, appointed to consider approval of new materials, has given extended consideration to the subject of use of stainless steels in pressure vessel construction, in an endeavor to formulate general rules. The problem has been found to be very involved and difficult, particularly as it is affected by the application of fusion welding in fabrication. Therefore, to meet the immediate needs of industry, the Boiler Code Committee proposes the following Cases for issuance, if found acceptable. They are submitted for public criticism and prompt comments are invited in order that they may be issued without undue delay.

It is expressly pointed out that these Cases are not to be considered effective until finally adopted by the Boiler Code Committee, notice of which will appear in Mechanical Engineering. If anyone has any comments to offer, they should be submitted to the Secretary of the Society. These comments will be turned over to the A. W. S. Welding Conference Committee for transmittal to the Boiler Code Committee.

CASE NO. 836

In item (3)(*a*), change heat-treatment minimum temperature from "1900° F." to "1950° F."

CASE NO. 861 (Reopened)

Inquiry: Case No. 834 covers Par. U-68 unfired pressure vessels of stabilized chrome-nickel steel conforming to A. S. T. M. Specifications A 167-35T, grade 4. This material is now covered by A. S. T. M. Specifications A 167-38T, grade 5, for columbium-bearing and grade 9 for titanium-bearing material. Will it be permissible to apply the Code symbol stamp to unfired pressure vessels fabricated to Par. U-69 omitting the heat-treatment and special tests required in the reply to Case No. 834?

Reply: It is the opinion of the Committee that stabilized austenitic chrome-nickel steel, conforming to A. S. T. M. Specifications A 167-38T, grades 5 and 9, may be used for vessels constructed to Par. U-69 with the following limitations:

(1) The chemical composition and physical properties are modified as follows from A. S. T. M. Specifications A 167-38T, grades 5 and 9:

Carbon, max., per cent	0.07
Manganese, per cent	0.40–2.50
Chromium, min., per cent	17
Nickel, min., per cent	9.5

Columbium,* min. = 10 times carbon content; 1 per cent max.

Titanium,* min. = 6 times carbon content; 0.60 per cent max.	
Tensile strength, min., lb. per sq. in.	75,000
Yield point, min., lb. per sq. in.	35,000
Elongation in 2 in., min., per cent	30

* Either columbium or titanium shall be used.

(2) Maximum temperature of 600° F.; maximum pressure of 400 lb. per sq. in.; maximum thickness 1/2 in.; allowable stress 15,000 lb. per sq. in., with a joint efficiency of 80 per cent.

(3) The last heating operation before welding shall consist of a softening treatment, that is, a heating to a minimum temperature of 1850° F., holding for not less than 1 hour per inch of thickness but in no case less than 30 minutes, and cooling rapidly and uniformly from that temperature. Heating after cold forming is not required.

Austenitic chrome-nickel stainless steels, when in a condition of internal stress and exposed to certain aqueous chloride solutions, or other corrosive environments, may fail by stress corrosion cracking. In order to take advantage of the omission of a stress relieving and stabilizing heat-treatment as covered by the preceding paragraphs of this reply, consideration should be given to the possibility of stress corrosion in the welds and affected zones.

(4) The composition of the deposited weld metal shall be within the following limits: The chromium and nickel content of the weld metal shall be within the same range as the parent metal; the columbium content of the weld metal, when columbium is used as a stabilizing element in the weld metal, shall be at least 9 times the carbon content of the weld metal and shall not exceed 1 per cent; the titanium content of the weld metal, when titanium is used as a stabilizing element of the weld metal, shall be at least 5 times the carbon content of the weld metal and shall not exceed 0.60 per cent. In case the chemical analysis of the first drillings of the weld metal fails to meet the foregoing specifications, two additional sets of drillings may be taken from the weld and the test shall be considered satisfactory if both these retest analyses meet the specifications.

(5) Vessels built under rules of Par. U-70 and otherwise conforming to the above limitations may be stamped accordingly but in this case the maximum allowable pressure shall not exceed 100 lb. and the maximum service temperature shall not exceed 250° F. Allowable design stresses shall be 25 per cent greater than specified for carbon steel in U-70.

CASE A

The following new case is suggested:

Inquiry: Will it be permissible to apply the Code symbol stamp to unfired pressure vessels fabricated by fusion welding of chromium-nickel steels conforming to A. S. T. M. Specifications A 167-38T, grades 2, 4, 6 if there is no heat-treatment following the welding?

Proposed Reply: It is the opinion of the Committee that austenitic chromium-nickel steel conforming to A. S. T. M. Specifications A 167-38T, grades 2, 4 and 6, may be used for vessels constructed to Par. U-69, with the following limitations:

(1) The chemical composition and physical properties shall be modified as follows: In all cases carbon 0.07 per cent maximum shall be required.*

In all cases manganese shall be specified as 0.40 to 2.50. Chromium and nickel content shall meet the minimum specified, but the exact range is subject to agreement between purchaser and manufacturer to obtain the optimum combination for the service. Tensile strength shall be 75,000 lb. per sq. in. minimum. Yield strength (0.2 per cent set) shall be 35,000 lb. per sq. in. minimum. Elongation in 2 in. shall be 30 per cent minimum.

(2) The last heating operation before welding shall consist of a full softening treatment, that is, heating to a minimum temperature of 1850° F. for grades 2 and 4, and 1950° F. for grade 6, holding for not less than 1 hour per inch of thickness but in no case less than 30 minutes, and cooling rapidly and uniformly from that temperature. Heating after cold forming is not required.

(3) Maximum service temperature shall be limited to 600° F.; allowable working stress shall be 15,000 lb. per sq. in., with a joint efficiency of 80 per cent.

(4) Maximum thickness of the shell of these vessels shall not exceed 3/8 in.

(5) Use of vessels constructed under the regulations of this inquiry shall be limited to service in which the prospective corrodents shall be none other than steam or water, or to vessels in which the stainless steels shall be used to protect contents of the vessel from products of metallic corrosion rather than to prevent corrosion of the vessel itself.

Austenitic chrome-nickel stainless steels, when in a condition of internal stress and exposed to certain aqueous chloride solutions may fail by stress corrosion cracking. Consideration should be given to the possibility of stress corrosion cracking in this and other corrosive environments to which the vessel may be exposed.

(6) Vessels built under the rules of Par. U-70 and otherwise conforming to the above limitations may be stamped accordingly, but in this case the maximum allowable pressure shall not exceed 100 lb. and the maximum service temperature shall not exceed 250° F. Allowable design stresses shall be 25 per cent greater than specified for carbon steel in U-70.

CASE B

The following case is suggested:

Inquiry: In Case No. 836 permission is given to fabricate unfired pressure vessels by fusion welding of chrome-nickel-molybdenum steel conforming to A. S. T. M. Specifications A 167-38T, grade 6, in accordance with Par. U-68 with specific limitations as to composition, heat-treatment, and use. Is it permissible to use this same material for vessels constructed in accordance with Par. U-69, with the same limitations as to heat-treatment? Radiographing of the thinner wall vessels covered by this paragraph would seem to be unnecessary.

Proposed Reply: It is the opinion of the Committee that unfired pressure vessels fabricated of austentic chrome-nickel-molybdenum steel conforming to A. S. T. M. Specifications A 167-38T, grade 6, will meet the intent of the Code, provided such vessels are constructed in accordance with Par. U-69 with the following limitations:

(1) The chemical composition and physical properties shall be modified as follows from A. S. T. M. Specifications A 167-38T, grade 6:

Carbon,* max., per cent	0.07
Manganese, per cent	0.40–2.50
Chromium and nickel content shall meet the minimum, the exact range being subject to agreement between purchaser and manufacturer to obtain the optimum combination for the service.	
Tensile strength, min., lb. per sq. in.	75,000
Yield point, min., lb. per sq. in.	35,000
Elongation in 2 in., min., per cent	30

(2) Maximum temperature, 600° F.; allowable stress 14,000 lb. per sq. in., with a joint efficiency of 80 per cent.

* NOTE: The carbon analysis shall be considered to the nearest hundredth of one per cent.

* NOTE: The carbon analysis shall be considered to the nearest hundredth of one per cent.

(3) The complete vessel shall receive one of the two following heat-treatments:

(*a*) Heating to a minimum temperature of 1950° F., holding for a period of 1 hour per inch of thickness but in no case less than 15 minutes, and cooling rapidly and uniformly from that temperature.

It is important that internal stresses due to quenching be kept to a minimum in order to avoid stress corrosion. Therefore, the quenching should proceed as uniformly as possible, quenching from both sides wherever practicable and avoiding steam pockets by auxiliary cooling. The purpose of this heat-treatment is to provide maximum over-all corrosion resistance.

Austenitic chrome-nickel stainless steels, when in a condition of internal stress and exposed to certain aqueous chloride solutions may fail by stress corrosion cracking. Consideration should be given to the possibility of stress corrosion cracking in this and other corrosive environments to which the vessel may be exposed in cases where the vessels are to be quenched in accordance with the preceding paragraph.

(*b*) Heating to 1600–1650° F., holding sufficiently long to provide freedom from susceptibility to intercrystalline corrosion, and cooling in a still atmosphere.

The purpose of this heat-treatment is to place the vessel in a state of minimum internal stress.

(4) Production test plates similar to those required for Par. U-68 construction shall be made for each vessel or each 200 ft. of weld in duplicate vessels and these test plates shall meet the welding process qualification requirements for Par. U-69 construction in carbon steel. These welded test plates shall be made from the same lot of material as the vessel itself. They shall be heat-treated with the vessels so as to duplicate as closely as possible the physical condition of the material in the vessel wall.

(5) The free-bend test specimen shall be ground and polished and the specimen immersed in boiling copper-sulphate sulphuric-acid solution for a minimum period of 48 hours. This solution shall consist of 47 cc. concentrated sulphuric acid and 13 grams of crystalline copper sulphate ($CuSO_4.5H_2O$) per liter of water. After immersion, the samples shall be bent as specified in Par. U-68. The elongation on the outside fibers shall be not less than 20 per cent, at which there shall be no evidence of fissuring.

(6) Representative drillings of the weld metal shall be obtained from one of the welded test plates and the chemical analysis of the weld metal shall be within the same range as the parent metal. In case the chemical analysis of the first drillings of the weld metal fails to meet the foregoing specifications, two additional sets of drillings may be taken from the same welded test plate, and the test shall be considered satisfactory, if both these retest analyses meet the specifications.

(7) The above provisions may be applied also to chrome-nickel-molybdenum steel as covered above with columbium or titanium additions. Vessels of chrome-nickel molybdenum steel of the composition and physical properties covered by (1), where the columbium or titanium content is a minimum of 60 per cent of that required in the reply to Case No. 834, may be constructed in accordance with the requirements of this case.

The lower columbium and titanium content permitted for the chrome-nickel-molybdenum steel is due to the stabilizing effect of the molybdenum content.

CASE C

The following case is suggested:

Inquiry: In Case No. 834 permission is given to fabricate unfired pressure vessels by fusion welding of chrome-nickel steel conforming to A. S. T. M. Specifications A 167-35T, grade 4, stabilized with columbium or titanium, in accordance with Par. U-68 with specific limitations as to composition, heat-treatment, and use. This material is now covered by A.S.T.M. Specifications A 167-38T, grade 5 for columbium-bearing, and grade 9 for titanium-bearing material. Is it permissible to use this same material for vessels constructed in accordance with Par. U-69 with the same limitations as to heat-treatment? Radiographing of the thinner wall vessels covered by this paragraph would seem to be unnecessary.

Proposed Reply: It is the opinion of the Committee that unfired pressure vessels fabricated of austenitic chrome-nickel steel conforming to A. S. T. M. Specifications A 167-38T, grades 5 and 9, will meet the intent of the Code, provided such vessels are constructed in accordance with Par. U-69 with the following limitations:

(1) The chemical composition and physical properties shall be modified as follows from A. S. T. M. Specifications A 167-38T, grades 5 and 9:

Carbon, max., per cent	0.07
Manganese, per cent	0.40 to 2.50
Chromium, per cent	at least 17
Nickel, per cent	at least 9.5
Tensile strength, min., lb. per sq. in.	75,000
Yield point, min., lb. per sq. in.	35,000
Elongation in 2 in., min., per cent	30

(2) Maximum temperature 700° F.; allowable stress 15,000 lb. per sq. in., with a joint efficiency of 80 per cent.

(3) The complete vessel shall be heat-treated as follows:

A vessel of columbium-bearing steel shall be treated at a temperature not less than 1550° F. and held at that temperature for a period of time proportioned on the basis of at least 1 hour per inch of thickness, but in no case less than 2 hours. A vessel of titanium-bearing steel shall be treated at a temperature not less than 1550° F. and not to exceed 1650° F. and held at that temperature for a period of time proportioned on the basis of at least 1 hour per inch of thickness but in no case less than 4 hours. The complete vessel shall be heat-treated as a unit, no local stress relieving being permitted, and it shall be allowed to cool slowly in a still atmosphere.

(4) Production test plates similar to those required for Par. U-68 construction shall be made for each vessel or each 200 ft. of weld in duplicate vessels and these test plates shall meet the welding process qualification requirements for Par. U-69 construction in carbon steel. These welded test plates shall be made from the same lot of material as the vessel itself. They shall be heat-treated with the vessels so as to duplicate as closely as possible the physical condition of the material in the vessel wall.

(5) The free-bend test specimen shall be ground and polished and the specimen immersed in boiling copper sulphate sulphuric acid solution for a minimum period of 48 hours. This solution shall consist of 47 cc. concentrated sulphuric acid and 13 grams of crystalline copper sulphate ($CuSO_4.5H_2O$) per liter of water. After immersion, the samples shall be bent as specified in Par. U-68. The elongation on the outside fibers shall be not less than 20 per cent, at which there shall be no evidence of fissuring.

(6) Representative drillings of the weld metal shall be obtained from one of the welded test plates and the chemical analysis of the weld metal shall be within the same range as the parent metal. In case the chemical analysis of the first drillings of the weld metal fails to meet the foregoing specifications, two additional sets of drillings may be taken from the same welded test plate, and the test shall be considered satisfactory if both these retest analyses meet the specifications.

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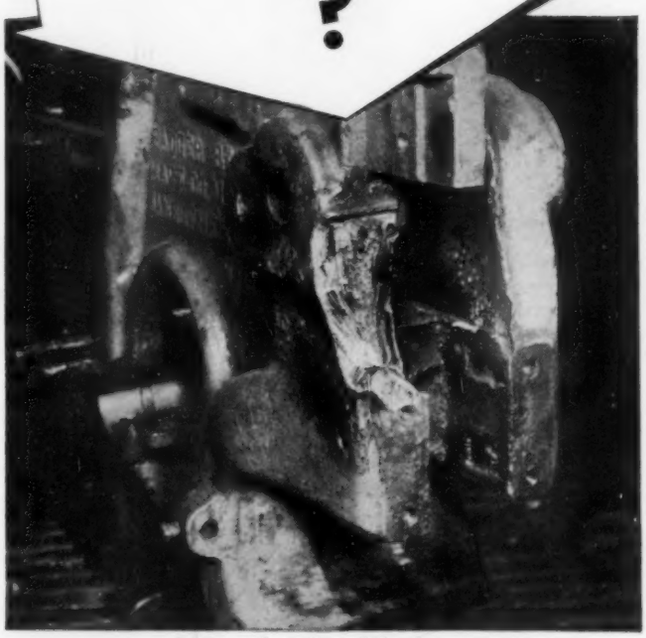

Fractured casting of the shear

WHEN this 3″ thick shear casting fractured, repair welding with cast iron rods seemed to be the answer. Further consideration and inspection, however, revealed that if this method were used, it would be necessary to preheat the entire casting in a furnace to avoid uneven strains in the metal.

To do this was impractical for, after being heated, the casting would have thrown off so much heat that no one could have gone near it to do the work.

Why not figure how you would have done this job? Then check your answer with the solution on page 573.

39134

Check your answer with the solution on page 573

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Welding Society ACTIVITIES — Related Events

STANDARD QUALIFICATION PROCEDURE

In the development of welding applications, progress has been made by offering to the user definite assurance of the integrity of the welds. The most positive determination for this is the non-destructive exploration or test of the welded joint, but where that form of test does not appear to be warranted, the plan of qualifying the welding operator by tests of welds made by him is by common consent regarded as the most effective safeguard for weld quality. In fact, most of the welding codes and specifications recently formulated contain more or less complete requirements for such qualification tests, some of which are applicable even when non-destructive tests of the welds are called for.

Due to the varying conditions under which these qualification practices have arisen there appears to be little uniformity among them and the variations, involving tests of both process and operators, have caused considerable confusion. Neither the manufacturers, contractors, nor the welding operators appear to be satisfied with present practices.

The AMERICAN WELDING SOCIETY'S "Standard Qualification Procedure," first issued in 1936 and revised in 1938, represents an intensive study by the Committee on Standard Qualification Procedure with the object of consolidating and standardizing the various tests that have been in use for qualifying welding processes and operators. While the immediate need for an authoritative set of rules has thus been fulfilled, the full value of the work will not be realized until the rules are universally adopted and embodied in all the codes and specifications to which they logically pertain. It is a matter of interest to report, therefore, that these rules have been embodied, either in whole or in part, in the following codes and specifications:

A. S. M. E. Power Boiler Code
A. S. M. E. Unfired Pressure Vessel Code
A. W. S. Tentative Code for Fusion Welding and Flame Cutting in Machinery Construction
A. S. M. E. Code for Pressure Piping
A. W. S. Specifications for Welded Highway & Railway Bridges
A. W. S. Rules for Fusion Welding Steam Oil or Air Piping in Marine Construction
A. W. S. Tentative Rules for Welding of Oil Storage Tanks
A. S. M. E. Miniature Boiler Code
A. P. I.-A. S. M. E. Code for Unfired Pressure Vessels
A. P. I. Code for Oil Storage Tanks
A. W. W. A. Code for Pressure Piping
A. W. S.-I. A. A. Code for Gravity Tanks, Tank Risers and Towers

In addition there are many other organizations, governmental and regulatory bodies that have adopted the A. W. S. code in whole or in part.

Purpose of Qualification Tests

The quality of a non-pressure welded joint will be determined by the specific process used and by the ability of the welding operator to apply that process. Predictable results as to the physical properties and soundness of such joints can be secured only by strict adherence to a fixed procedure of welding which has been properly investigated. It cannot be expected that good results will be obtained even by careful and painstaking workmen if poor materials, inadequate or wornout equipment are used, or if fundamentally improper methods are pursued. Nor can the purpose of welding be attained by the mere adoption of a carefully outlined process of welding if the workmen are not adequately trained to follow that process, and properly supervised to be certain that all essential details of the specific process are followed.

The Committee has in mind constant simplification of the Qualification Procedure to the end that it shall be less burdensome on industry without sacrificing important safety conditions. To this end it will undoubtedly group a number of the variables so that requalification will not be necessary so long as the variation in procedure and processes are not beyond certain prescribed limits where requalification would become mandatory.

S.S. E. J. HENRY

Chester, Pa., July 29th—With the launching today of the S.S. E. J. Henry at the yards of the Sun Shipbuilding and Dry Dock Company, The Atlantic Refining Company added to its fleet the third of a group of new 18,100-ton welded tankers which are the world's largest welded ships and the first turbo-electric tankers built in the United States. The newest addition to the fleet was christened by Mrs. E. J. Henry, wife of the vice-president of The Atlantic Refining Company for whom the vessel was named. A number of welding people witnessed the launching.

The S.S. E. J. Henry, The Atlantic Refining Company's New 18,100-Ton Tanker, in the Delaware River Immediately After Her Launching at the Sun Shipyards, Chester, Pa., July 29th

The 18,100-Ton Oil Carrier, the S.S. E. J. Henry, Leaves the Ways at the Sun Shipyards, Chester, Pa., on July 29th. The New Tanker Is the Latest Addition to The Atlantic Refining Company's Fleet

The S.S. E. J. Henry is similar in design to her sister ships, the S.S. J. W. Van Dyke and the S.S. Robert H. Colley, both commissioned in 1938, but the new vessel marks a further advance in the marine application of high-pressure, high-temperature steam generating systems. While the two earlier tankers have steam generating systems operating at 625 pounds pressure and 835° F., the steam generating system of the S.S. E. J. Henry will operate at the same pressure but at a steam temperature of 910° F. The turbo-electric engines are designed to develop 5000 horsepower and will give a speed of 13.25 knots.

The new vessel is built on the longitudinal bracketed system, with nine center tanks and nine wing tanks on each side. Over-all length is 541 feet 5 inches. Cargo capacity is 156,000 barrels, or 6,552,000 gallons, enough gasoline to drive 100 cars of the moderate price class 40 times around the world. Pumping equipment will make it possible to discharge the entire cargo in approximately 11 hours, about one-third the usual discharge time.

The S.S. E. J. Henry will join her two sister ships on the run between Philadelphia and Texas Gulf ports in September.

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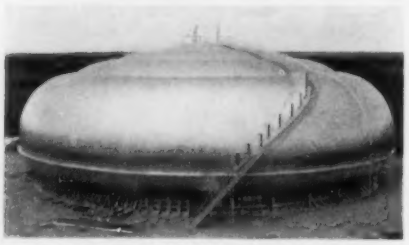
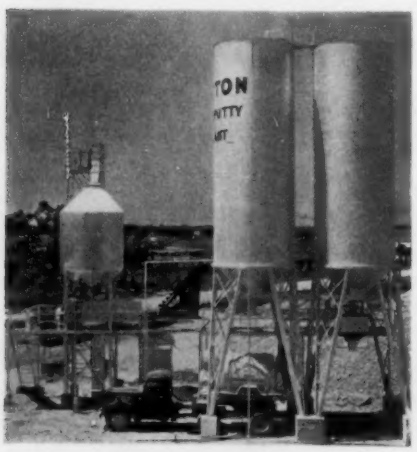
It is estimated that in steady operation on this run the three tankers could supply the entire gasoline requirements of Philadelphia and its suburbs.

WELDED TANKS



This Hortonspheroid was built for Hanlon-Buchanan, Inc., at Corpus Christi, Texas. It has a capacity of 100,000-bbls. and is designed to store natural gasoline under a pressure of 10 lb. per sq. in.

The illustration below shows standard two tank Brooks-Taylor lime putty plant built for the State Sand & Gravel Company at Indianapolis, Indiana. This plant was fabricated at the Chicago Bridge & Iron Company's Birmingham shop and shipped to Indianapolis ready to be assembled. It is used in producing aged lime putty from quick lime.



ENGINEERING PHYSICAL METALLURGY

A new book of 549 pages with 250 illustrations has just been published by the D. Van Nostrand Company, Inc., 250 Fourth Avenue, New York. The author, Robert H. Heyer, has in a single volume produced a simple treatment of the field adopted to the instruction of non-metallurgical students. In this book, processing operations, including hot and cold reduction and fabrication, welding, heat treating and machining, are discussed primarily from the metallurgical rather than from the operational viewpoint. Price $4.50.

WELDED MACHINERY

German Book on the Design of Welded Machinery: Schweisskonstruktionen, by R. Hänchen, published by J. Springer, Berlin, 1939, 8 x 11 in., 123 pp. 491 illustrations, 18.60 RM. This is the ninth volume of the publisher's series on design of machine details. Levers, bearing blocks, machine bases, winding drums, piping, cranes and boilers are designed for welding with special reference to fatigue loads.

TWIN LAUNCHING

The identical 110-ft. Coast Guard Cutters RARITAN and NAUGATUCK began their designed career of disciplined service at the plant of the Defoe Boat & Motor Works, Bay City, Michigan, by descending the launching ways in twin formation.

The Twin Launching

Ropes were cut simultaneously on both ships and they struck the water about a second and a half apart, heeling spectacularly to 60° as they did so and dipping up tons of water which spurted from the freeing ports in their bulwarks as they righted.

The "Naugatuck" as She Starts Her Trial Trip and Unexpected, Unplanned Ice Test

The ships are harbor cutters, one to be stationed at Boston and the other at Philadelphia, and their duties will consist of general harbor work such as customs boarding duty, ice breaking, fire protection and general assistance to shipping. Each is equipped with diesel-electric main power plant, delivering 1000 shaft horsepower, and with its Baltic type bow and heavy waterline plating is capable of heavy ice breaking.

Eight Electric Arc Welders were used in the construction of these two Coast Guard Cutters. The entire hull and house structures are electric welded. Pilot house front is made of manganese silicon

Demonstrating the Cutters' Ice-Breaking Ability During the Trial of the Vessels in Saginaw Bay

bronze which is electric arc welded to steel structure. House portlights—there are no portlights in the hull—are monel metal similarly arc welded to the house sides. Monel button type floor plates are also welded to steel in galley and toilets and are used for treads at doors to deck.

Speed developed on trials was 13.1 knots maximum at 265 r.p.m. of propeller and 1010 hp. of engines.

SHAWINIGAN CARBIDE

For OXY-ACETYLENE WELDING AND CUTTING OF METALS

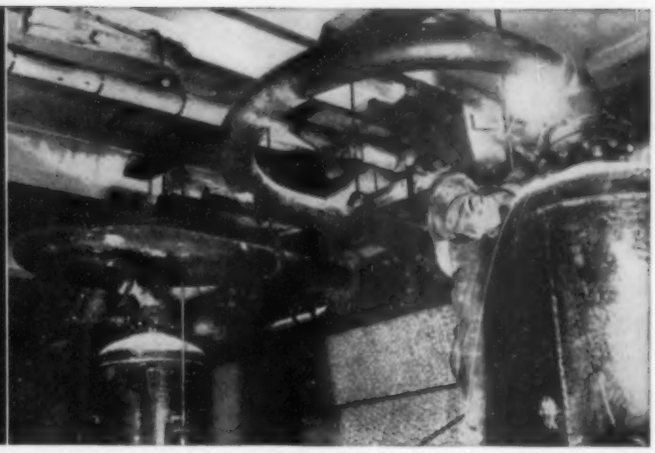
SHAWINIGAN PRODUCTS CORPORATION
EMPIRE STATE BUILDING
NEW YORK, N.Y.

THOMSON

HEADQUARTERS FOR
Manual and Automatic SPOT, SEAM, BUTT, FLASH, PROJECTION, PORTABLE GUN, FABRIC and SPECIAL RESISTANCE WELDING PRODUCTION EQUIPMENT
Write for FLASHES, a monthly magazine of Resistance Welding News and information. Sent free on request by
THOMSON-GIBB ELECTRIC WELDING CO.
General Offices: 166 PLEASANT ST., LYNN, MASS.

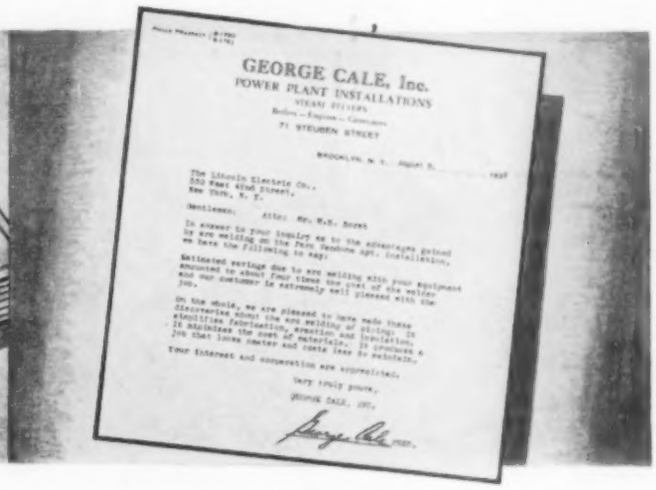
400% returned in 4 months!

Here's how—



1. THEY BOUGHT Contractors George Cale, Inc., Brooklyn, N.Y. purchased a 200-amp. *"Shield-Arc."* The Self-Indicating "Job Selector" and Current Control of this new Lincoln Welder provide the right TYPE and INTENSITY of arc for lowest cost and highest quality on every welding job.

2. THEY WELDED 6000 ft. of 2" to 12" steam lines in an Apartment Building. Used 1400 lbs. of "Fleetweld 5"—the world's favorite pipe welding electrode. Produces welds that are stronger than the pipe itself.



GEORGE CALE, Inc.
POWER PLANT INSTALLATIONS
STEAM FITTERS
Boilers—Engines—Condensers
71 STEUBEN STREET

3. THEY SAVED On this one job, over a 4-month period, total savings due to Lincoln arc welding as compared to other methods of welding or fabrication amounted to four times the cost of their new *"Shield-Arc"* Welder.

4. THEY SAY "We are pleased to have made these discoveries about the arc welding of piping: It simplifies fabrication, erection and insulation. It minimizes the cost of materials. It produces a job that looks neater and costs less to maintain."

You, too, can profit with *"Shield-Arc"* welding. Consult the nearest Lincoln office or mail the coupon for details.

Largest Manufacturers of Arc Welding Equipment in the World

THE LINCOLN ELECTRIC COMPANY

CLEVELAND, OHIO

THE LINCOLN ELECTRIC CO., Dept. DD-638, Cleveland, O.

Send free bulletin of the *"Shield-Arc"* Welding of Piping.

Name _____ Position _____

Company _____

Address _____

City _____ State _____

"Naugatuck" Rescues Oil Tankers on Trial Trip Breaking Six-Mile Path Through Ice, Sometimes 18 Inches Thick

Unexpected Ice Tests Feature Trial Trips

Dame Fortune provided for the two days of the trials a practically perfect ice test for the ships which had not been hoped for. The NAUGATUCK out for trials on Saginaw Bay discovered that two oil tankers of the Great Lakes Transport Company were helplessly locked in a field of solid green ice 12 to 14 inches thick, and made short work of breaking them through the six-mile wide barrier. The following day, at the request of the owners of the tankers, the RARITAN on her trials led them both out again through the field.

OBITUARY

AUBREY WEYMOUTH

Civil Engineer and Trustee of Lehigh University Dies at 66

Aubrey Weymouth of Flushing, N. Y., for the last thirty-five years a civil engineer with the firm here of Post & McCord, died July 27th at his home in his sixty-seventh year.

He was born in Richmond, Va., and was graduated from Lehigh University with the degree of civil engineer in 1894. Later he received the degree of Doctor of Civil Engineering from Lehigh University and was made a trustee of that institution. Mr. Weymouth was one of the promoters of the annual circus for the support of Flushing Hospital.

His widow, Alice White Weymouth, and two daughters, Mrs. Medora Peterson and Mrs. Martha Mooch, both of Great Neck, L. I., survive.

Mr. Weymouth served the Society as one of the organizers of the Structural Steel Welding Research Committee and one of its members. He served for a number of years as a member of the A. W. S. Executive Committee and played a prominent part in securing the adoption of the A. W. S. Building Code by the City of New York. He was also a member of the Welding Research Committee of the Engineering Foundation, which is sponsored jointly by the A. W. S. and the A. I. E. E. The Society has lost one of its "elder statesmen" whose wise council was sought on a number of occasions by the officers of the Society.

FIRST POLISH WELDING CONGRESS

The first Polish Welding Congress was held April 21st–23rd in Warsaw. It was organized by five Polish technical societies: The Association for the Development of Gas Welding and Oxygen Cutting in Poland, the Association of Metallurgists, the Association of Mechanical Engineers, the Association of Aeronautical Engineers and the Association of Civil Engineers. The Chairman of the Organization Committee was Dr. Stefan Bryla. Representatives from France, Germany and Yugoslavia were present.

As a result of the splendid success of the first Congress, a congress will be held every three years hereafter. In each intervening year there will be a Welding Day at the Annual Meeting of the Association for the Development of Welding and Oxygen Cutting in Poland.

ALLOW FUSION WELDING

I. C. C. Grants Application on Test Tank Cars

Special to The New York Times

WASHINGTON, July 26th.—The Interstate Commerce Commission today granted an application of the Association of American Railroads to authorize the General American Transportation Corporation to construct fifty additional test tank cars fabricated by fusion welding instead of the customary riveting for transportation of caustic soda solution.

The fusion welded cars are said to offer certain advantages over riveted cars for carrying this commodity because of the smooth inner surface to which caustic-resisting paint can be applied with greater success.

NOW HOLLUP OFFERS AN IMPROVED SUREWELD "N"

Better Appearance
Perfect Contour—Full Throat. Easy Slag Cleaning. Silver Bright Weld Bead.

Better Physicals

Better Economy
Quiet Soft Arc. Low Spatter Loss. Less Coating—5% More Steel. More Weld Deposit per Pound.

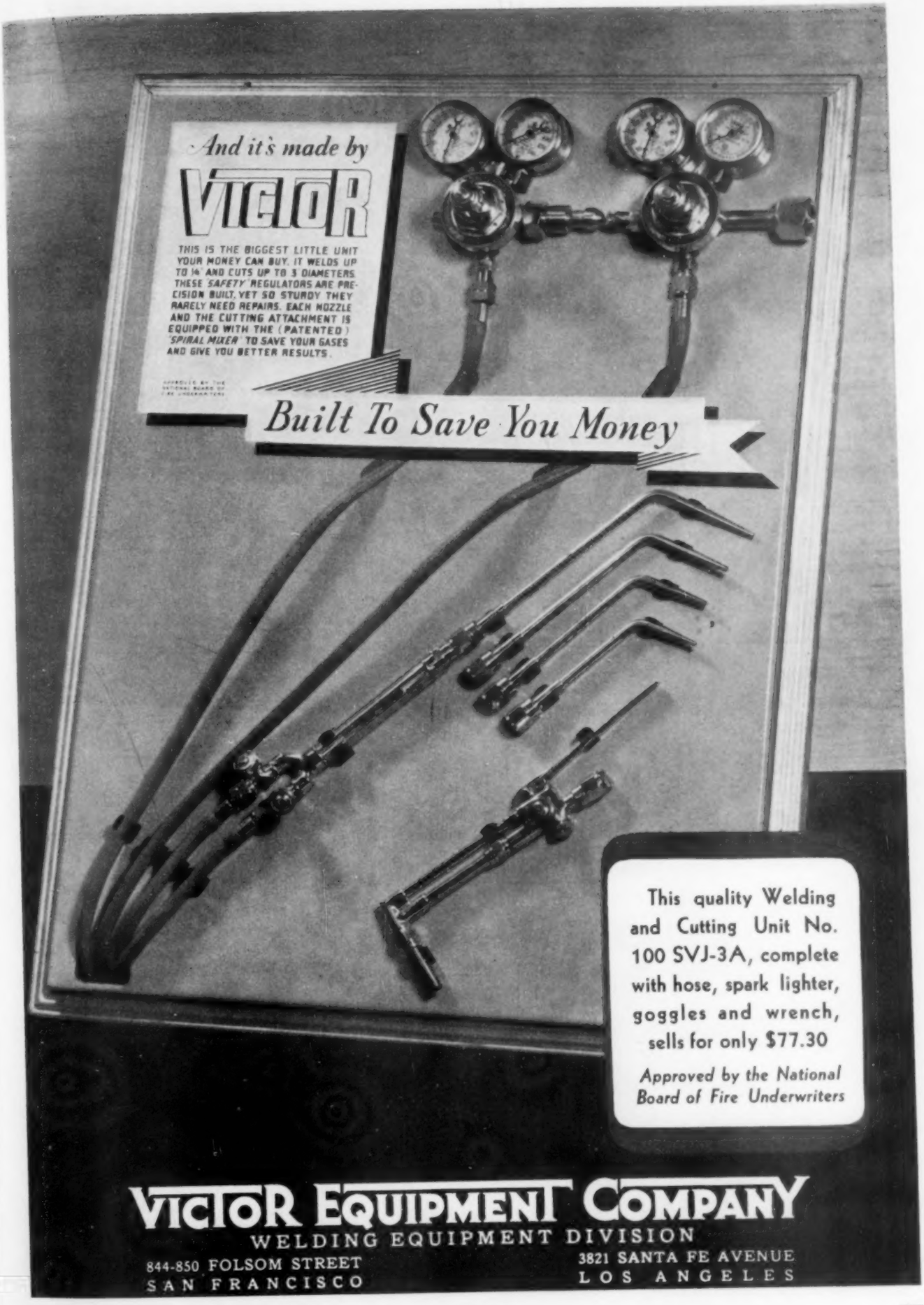
PITTSBURGH TESTING LABORATORY'S
GRADE REPORT OF JUNE 27th, 1939
TEST OF SUREWELD "N" ELECTRODES UNDER AMERICAN SOCIETY FOR TESTING MATERIALS SPECIFICATION A-205-37T

ELECTRODE	POLARITY	POSITION	TREATMENT	COMPLIES WITH GRADE
Sureweld N	Straight	Flat	Non-Stress Relieved	10
Sureweld N	Straight	Vertical	Non-Stress Relieved	10
Sureweld N	Straight	Overhead	Non-Stress Relieved	10
Sureweld N	Straight	Flat	Stress Relieved	10

The above materials exceed the requirements of Grades 15, 20, 30 and 40 and may be used when these Grades are specified.

IMPROVED SUREWELD "N" NOW AVAILABLE THROUGH ALL HOLLUP DISTRIBUTORS

HOLLUP CORPORATION
WELDING WIRE AND EQUIPMENT
3357 WEST 47TH PLACE • CHICAGO, ILLINOIS


And it's made by
VICTOR
THIS IS THE BIGGEST LITTLE UNIT YOUR MONEY CAN BUY. IT WELDS UP TO ¼" AND CUTS UP TO 3 DIAMETERS. THESE 'SAFETY' REGULATORS ARE PRECISION BUILT, YET SO STURDY THEY RARELY NEED REPAIRS. EACH NOZZLE AND THE CUTTING ATTACHMENT IS EQUIPPED WITH THE (PATENTED) 'SPIRAL MIXER' TO SAVE YOUR GASES AND GIVE YOU BETTER RESULTS.
Built To Save You Money
This quality Welding and Cutting Unit No. 100 SVJ-3A, complete with hose, spark lighter, goggles and wrench, sells for only $77.30
Approved by the National Board of Fire Underwriters
VICTOR EQUIPMENT COMPANY
WELDING EQUIPMENT DIVISION
844-850 FOLSOM STREET
SAN FRANCISCO
3821 SANTA FE AVENUE
LOS ANGELES

SELECTOR CHART

The Hollup Corporation of Chicago has just issued a very attractive Selector Chart in connection with the Hollup Electrodes which gives the trade name of the electrode and color and identification, use and the procedure to be followed, the current value, and the physical properties that may be expected from each type of electrode. Copy of the Chart will be sent on request.

LOOS PROMOTED

The AMERICAN WELDING SOCIETY received notification that effective July 17th, Mr. C. E. Loos has been appointed Manager of the Structural and Plate Bureau of the Metallurgical Division, Pittsburgh District of the Carnegie-Illinois Steel Corporation.

Friends in the Society wish Mr. Loos success in his new position. Mr. Loos is an active member of the A. W. S. Bridge Committee and author of a number of important papers presented before the Society.

WELDED "I" BEAMS REPLACE WOOD

When it was found necessary, for public safety, to replace the wood decking supports of a bridge—the Miami County Ohio Engineer called for arc welding.

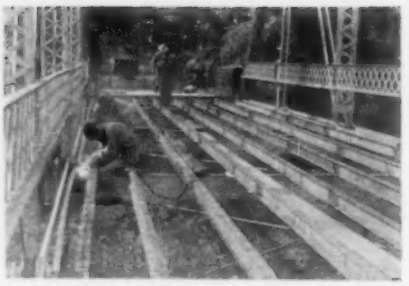


Photo courtesy Hobart Bros. Co., Troy, Ohio

Eight 12-inch stringers of standard "I" beams were welded. Inspection was made and officials were pleased with the speed and economy of the strengthening and repair work. Plans are now being made for the rebuilding of other bridges throughout the county of welded steel.

CONFERENCE

The International Conference on Flames and Furnaces organized by the Institute of Fuel, to be held in London, September 17–20, 1940, will devote a part of its Session VII on Formation of Flame to welding and cutting flames. Papers and correspondence in connection with the conference should be addressed to the Secretary, 54 Victoria Street, London S.W.1.

SPOT WELDING

Belgian Bulletin on Spot Welding: Les Soudures par Résistance Électrique, Bulletin No. 2 of the Materials Testing Laboratory of the University of Brussels. 85 pp. 1939. 20 Belgian Francs. Theoretical and experimental study of the strength of spot welds (three sheets) in mild steel 0.04–0.25 inch thick.

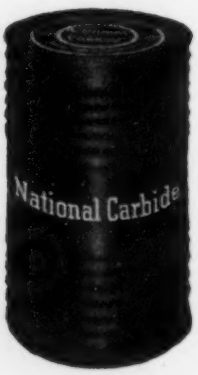
ENGINEERING PROJECTS

A Committee of the Engineering Societies of New England, Incorporated, 715 Tremont Temple, Boston has been at work for two months or more preparing information regarding "Works of Engineering Interest in New England to Which Engineering Visitors Are Welcome" for the purpose of providing this information to engineering visitors at the New York World's Fair in the hope that these engineering visitors will be induced to include New England in the itinerary of their trip to the Fair.

At the New England Exhibit at the Fair there will be posted a letter of invitation for engineers visiting the World's Fair to inspect New England's engineering works of interest and there will also be available for distribution at the New England Exhibit a pamphlet listing in detail engineering works in New England to which engineering visitors are welcome.

National

Carbide



DEPENDABLE

EFFICIENT

ECONOMICAL

FOR WELDING and CUTTING

Use National Carbide in the Red Drum

NATIONAL CARBIDE CORPORATION

Lincoln Building New York, N. Y.

when the average of many welders must be High . . .

Specify PAGE HI-TENSILE "F"

● A rod that fits every welder's style is valuable to you on jobs on which a number of welders are working—but on which results from each must meet the same standards.

In Page Hi-Tensile "F" you have this rod. It is fast—smooth-running. Good for work in tight places. Used equally well on horizontal, vertical and overhead jobs. It's quiet—and has little spatter and slag loss.

Hi-Tensile "F" is especially well adapted to work in CRO-MAN-SIL, COR-TEN, H.T.50 and other new alloy steels.

Your local Page distributor will give you some interesting information on Hi-Tensile "F" and other Page electrodes.

BUY ACCO QUALITY *in Page Welding Electrodes, Page Wire Fence, TRU-LAY Preformed Wire Rope, Reading-Pratt & Cady Valves, Campbell Abrasive Cutting Machines, American Chains and Wright Hoists, Cranes and Trolleys.*

PAGE STEEL AND WIRE DIVISION • MONESSEN • PENNSYLVANIA

See our exhibit, National Metal★ Exposition, Booth M-323

AMERICAN CHAIN & CABLE COMPANY, Inc.

AMERICAN CHAIN DIVISION • AMERICAN CABLE DIVISION • ANDREW C. CAMPBELL DIVISION • FORD CHAIN BLOCK DIVISION • HAZARD WIRE ROPE DIVISION • HIGHLAND IRON AND STEEL DIVISION • MANLEY MANUFACTURING DIVISION • OWEN SILENT SPRING COMPANY, INC. • PAGE STEEL AND WIRE DIVISION • READING-PRATT & CADY DIVISION • READING STEEL CASTING DIVISION • WRIGHT MANUFACTURING DIVISION • IN CANADA: DOMINION CHAIN COMPANY, LTD. • IN ENGLAND: BRITISH WIRE PRODUCTS, LTD. • THE PARSONS CHAIN COMPANY, LTD. • *In Business for Your Safety*

TENTATIVE PROGRAM

TWENTIETH ANNUAL MEETING AMERICAN WELDING SOCIETY WEEK OF OCTOBER 22, 1939

Headquarters: STEVENS HOTEL—CHICAGO, ILL.
Make Room Reservations Early—Direct with Stevens Hotel
Arrive Sunday 22nd—(Convention Hotel) Rates apply for Short or Long Stay

National Metal Exposition, International Amphitheater—Open Afternoons and Evenings Throughout the Entire Week

IMPORTANT

ALL Technical Sessions will positively start on time.

No Stenotype Reporter—Members desiring to discuss papers are urgently requested to prepare discussion in writing in advance of the meeting and to send copies to headquarters as those preparing written discussion will be given preference at the sessions. Members and guests giving extemporaneous discussion at meeting should forward a written transcript of discussion as soon as possible after the meeting.

Members and guests are urged to REGISTER immediately upon arrival at A. W. S. HEADQUARTERS and obtain Convention Badge admitting them to Exposition.

NO REGISTRATION FEE but a charge of 50¢ (per member) and $1.00 (non-member) is made for Technical Sessions Papers.

Registration hours throughout the week:

Stevens Hotel

Monday, Tuesday and Wednesday	9 a.m. to 5 p.m.
Thursday	9 a.m. to 7 p.m.
Friday	9 a.m. to 12 noon

International Amphitheater

Monday, Tuesday and Wednesday	12 noon to 10 p.m.
Thursday	12 noon to 6 p.m.
Friday	9 a.m. to 10 p.m.

PRESIDENT'S RECEPTION—SUNDAY, OCTOBER 22nd, 5 to 7 P.M.
Tower Ballroom, lower level

MONDAY, OCTOBER 23rd, Morning 9:30 A.M.
North Ballroom

KEYNOTE ADDRESS
by DAVID LEVINGER,
Asst. to the Vice-Pres. & Works Mgr.
Hawthorne Plant, Western Electric Company

PRESENTATION OF MEDALS

TECHNICAL SESSION

Chairman, H. C. BOARDMAN,
Chicago Bridge and Iron Company

Vice-Chairman, C. A. McCUNE,
Magnaflux Corporation

GOVERNMENT CONSTRUCTION WORK

Welded Structures Under the Bureau of Yards and Docks, U. S. Navy,
by Commander C. A. TREXEL, Bureau of Yards and Docks, Navy Department

Bonneville Dam Presents Varied Use of Welding,
by PAUL L. HESLOP and FRED T. DOWNING, Corps of Engineers, U. S. Army

Motion Picture on Grand Coulee Dam

ROEBLING

the custom-made wire for exacting welders

★ BARE WELDING ELECTRODES

★ COVERED WELDING ELECTRODES

★ GAS WELDING WIRE

ROEBLING WELDING CABLES:

Made in a complete line of rubber and braided types for arc welding purposes.

JOHN A. ROEBLING'S SONS COMPANY, TRENTON, N.J.
Branches in Principal Cities

ONLY A FINE PRODUCT MAY BEAR THE NAME ROEBLING

Monday, Afternoon—2:00 P.M.

SIMULTANEOUS TECHNICAL SESSIONS

South Ballroom

INDUSTRIAL RESEARCH

Chairman, G. F. JENKS, Col.
Ordnance Dept., U. S. Army

Vice-Chairman, C. H. JENNINGS,
Westinghouse Electric & Mfg. Co.

Weld Hardening of Carbon and of Alloy Steels
by H. J. FRENCH and T. N. ARMSTRONG, International Nickel Co.

An Investigation of the Spot Welding of Automobile Grade Mild Steel
by W. F. HESS and R. A. WYANT, Rensselaer Polytechnic Institute

Failure of Aluminum Subjected to Combined Stresses
by JOSEPH MARIN, Rutgers University

Fatigue Tests of Welded Joints in Structural Plates
by W. M. WILSON and A. B. WILDER, University of Illinois

North Ballroom

PRODUCTION WELDING IN LIGHT GAGE MATERIAL

Chairman, R. E. McFARLAND,
Western Elec. Co.

Vice-Chairman, E. A. BALSLEY,
Chairman, Chicago Section

Welding Propeller Shaft Tubing for the Automotive Industry
by G. C. GRIDLEY, Mechanics Universal Joint Division, Borg-Warner Corporation

Machine Welded Sheet Metal Parts for Enameling
by JOSEPH C. LEWIS, Associated Engineers, Inc.

Automatic Oxyacetylene Welding of Oil Floats
by H. E. LERNER, Taylor Sales Engineering Company

Evening—7:30 P.M.

Industrial Research Conference—Col. G. F. JENKS, **Chairman,** presiding

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TUESDAY, OCTOBER 24th, Morning—9:30 A.M.

SIMULTANEOUS TECHNICAL SESSIONS

South Ballroom

FUNDAMENTAL RESEARCH

Chairman, J. J. CROWE,
Air Reduction Sales Co.

Vice-Chairman, MILTON MALE,
U. S. Steel Corp. of Delaware

Reactions in Arc Welding
by R. DAVID THOMAS, JR., Arcos Corporation, and F. H. RHODES, Cornell University

Arc Welding in Controlled Atmospheres
by G. E. DOAN, Lehigh University

The Effect of Alloying in Metallic Arc Welding
by R. W. EMERSON, Westinghouse Elec. & Mfg. Co.

Manganese in Rutile-Type Coated Steel Electrodes
by E. G. ENCK, Foote Mineral Company

Creep Tests of Arc-Welded Low-Carbon Steel
by N. F. WARD, University of California

North Ballroom

MACHINERY CONSTRUCTION

Chairman, A. E. GIBSON,
The Wellman Eng. Co.

Vice-Chairman, C. M. UNDERWOOD,
U. S. Naval Gun Factory

Use of Steel Castings and Rolled Steel Plate in Welded Fabrication
by H. J. SHIFFLI and E. L. KREJCI, American Steel Foundries

Plate Edge Preparation for Welding
by H. E. ROCKEFELLER, The Linde Air Products Co.

Flow of Materials in Production Welding
by W. W. PETRY, Cincinnati Milling Machine Co.

Welding Heavy Presses
by L. J. McDONOUGH and J. R. HENRY, Clearing Machine Corp.

Afternoon—2:00 P.M.

SIMULTANEOUS TECHNICAL SESSIONS

South Ballroom

FUNDAMENTAL RESEARCH

Chairman, K. L. HANSEN,
Harnischfeger Corp.

Vice-Chairman, A. M. CANDY,
Hollup Corporation

Further Studies of the Spot Welding of Low Carbon and Stainless Steels
by W. F. HESS and R. A. WYANT, Rensselaer Polytechnic Institute

Application of Proximity Effect to Welding
by E. BENNETT, Univ. of Wisconsin

Contact Resistance
by F. J. STUDER, Union College

Weld Inspection by Means of Trepanned Plugs
by W. T. TIFFIN, University of Oklahoma

Welding of Copper
by A. P. YOUNG, Michigan College of Mining & Technology

North Ballroom

WELDING IN EQUIPMENT CONSTRUCTION

Chairman, J. W. OWENS,
Fairbanks-Morse Co.

Vice-Chairman, O. T. BARNETT,
Black, Sivalls & Bryson, Inc.

The Fabrication of Road Building Equipment
by L. L. BURGER, LaPlant-Choate Mfg. Co. Inc.

Designing Construction Machinery for Production by Welding
by H. C. HETTELSATER, Harnischfeger Corp.

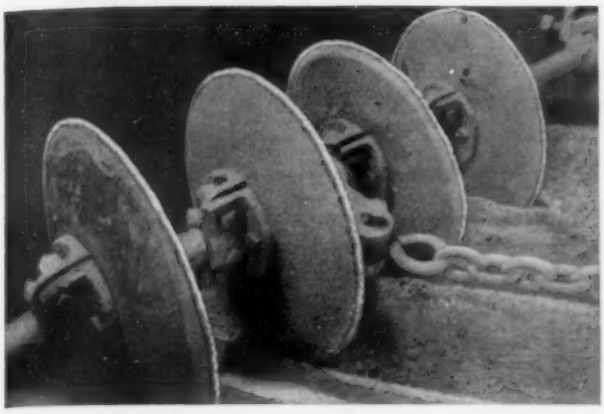
Cutting and Welding Stainless Clad Steel
by W. B. KEELOR,
Farwell Metal Fabricating Div., Farwell, Ozmun, Kirk & Co.

Large Equipment Fabrication
by LESLIE McPHEE, Whiting Corp.

Evening—7:30 P.M.

Fundamental Research Conference—H. M. HOBART, **Chairman,** presiding

REDUCE WEAR BY HARD-FACING
with Haynes Stellite Alloy



MINING—The edges of these roaster rabble disks, hard-faced with Haynes Stellite alloy $\frac{1}{16}$-inch thick, show little wear in 6 months. Disks not hard-faced wore down 7 in. in the same period.

FOOD—Steel scraper blades for dough molding machines wore out in a month, but this blade, its edge hard-faced with Haynes Stellite alloy, will be sharp and tarnish-free indefinitely.

AIRCRAFT—Seaplane pontoon lugs are hard-faced with Haynes Stellite rod for greatly increased life. The lugs, used as fastenings for mooring cables, must resist abrasion and corrosion.

PAPER—Chipper knives for this wood hog, flame-cut from steel plate and hard-faced with Haynes Stellite rod, cost $\frac{2}{3}$ as much as high-carbon steel knives and last 4 to 6 times as long.

Write for the 104-page book, "Hard-Facing With Haynes Stellite Products," which shows how these products can reduce wear and save money for you. There is no obligation.

PRODUCT OF A UNIT OF UCC UNION CARBIDE AND CARBON CORPORATION

"Haynes Stellite" is a registered trade-mark of Haynes Stellite Company.

HAYNES STELLITE TRADE MARK

Red-hard, wear-resisting alloy of cobalt, chromium and tungsten

HAYNES STELLITE COMPANY

Unit of Union Carbide and Carbon Corporation

UCC

Chicago · Cleveland · Detroit · Houston · Los Angeles · New York · San Francisco · Tulsa

General Office and Works—Kokomo, Indiana
Foreign Sales Department—New York City

Haynes Stellite hard-facing rods and information on other Haynes Stellite Company products also are available through all apparatus shipping points of The Linde Air Products Company

WEDNESDAY, OCTOBER 25th, Morning—9:30 A.M.

SIMULTANEOUS TECHNICAL SESSIONS

South Ballroom

FLAME HARDENING & HARD SURFACING

Chairman, M. M. WEIST,
Air Reduction Sales Co.

Vice-Chairman, R. S. KENRICK,
The Welding Engineer

Flame Hardening the Way Surfaces of Machine Tools
by FRED C. DULL, The Monarch Machine Tool Company

Hard Facing by Fusion Welding
by T. B. JEFFERSON,
Marine Design Section, Office of Chief of Engineers, War Dept.

Flame Treating
by J. H. ZIMMERMAN, The Linde Air Products Company

Flame Hardening from the Standpoint of the Commercial Heat Treater
by W. G. HAMILTON, Accurate Steel Treating Co., Inc.

North Ballroom

RESISTANCE WELDING

Chairman, G. S. MIKHALAPOV,
Heintz Mfg. Co.

Vice-Chairman, D. H. COREY,
Detroit Edison Company

Some Applications of the Resistance Welding Process
by C. L. PFEIFFER, Western Electric Company

Precision Welding by the Resistance Method
by E. J. BATES, G. J. OSWALD and R. L. HOUS
The National Cash Register Co.

Spot Welding of Aluminum
by R. KAUFFMANN, Aluminum Français

Some Studies of Flash Welding
by M. G. Yatsevitch, Watertown Arsenal

Afternoon—2:00 P.M.

SIMULTANEOUS TECHNICAL SESSIONS

South Ballroom

WELDED PIPING, PRESSURE VESSELS AND BOILERS

Chairman, D. S. JACOBUS,
The Babcock & Wilcox Co.

Vice-Chairman, E. VOM STEEG, Jr.,
General Electric Company

Welding of Boiler Drums and Pressure Vessels
by R. T. KERNOLL, Edge Moor Iron Works

Oxyacetylene Welding Red Brass Pipe
by A. N. KUGLER, Air Reduction Sales Co.

90° Welded Nozzles, Piping—Calculations, Design and Fabrication
by F. C. FANTZ and W. G. HOOPER,
Midwest Piping & Supply Co. Inc.

Extensions of Fusion Welding in Special Pipe and Pipe Fitting Applications
by E. HALL TAYLOR, Taylor Forge and Pipe Works

North Ballroom

RESISTANCE WELDING

Chairman, J. D. GORDON,
The Taylor Winfield Corp.

Vice-Chairman, M. S. CLARK,
Federal Machine & Welder Co.

Engineering Fundamentals of Resistance Welding
by S. M. HUMPHREY, The Taylor Winfield Corp.

High Speed Welding Assemblies
by E. W. FORKNER, Federal Machine & Welder Co.

Application and Use of Portable Spot Welders
by C. E. HEITMAN, Edward G. Budd Mfg. Co.

Latest Developments in Resistance Welding
by R. T. GILLETTE, General Electric Company

Evening—10 P.M. to 1 A.M.—Boulevard Room—Stag Party—Food—Entertainment—Refreshment—Price $1.00

THURSDAY, OCTOBER 26th, Morning—9:30 A.M.

SIMULTANEOUS TECHNICAL SESSIONS

South Ballroom

CUTTING & WELDING IN STEEL MILLS

Chairman, L. C. BIBBER,
Carnegie-Illinois Steel Corp.

Vice-Chairman, H. E. ROCKEFELLER,
The Linde Air Products Company

Repairs to Castings and Other Steel Mill Parts
by S. S. BAUMER, Bethlehem Steel Co.

Welding in a Steel Mill
by R. P. PALMER, Wheeling Steel Corp.

Flame Descaling and Flame Cleaning and Dehydrating
by J. G. MAGRATH, Air Reduction Sales Co.

North Ballroom

WELDING IN STRUCTURAL & SHIP WORK

Chairman, EVERETT CHAPMAN,
Lukenweld, Inc.

Vice-Chairman, A. G. BISSELL,
Bureau of Construction & Repair, Navy Dept.

High Spots in Ship Welding
by E. D. DEBES, Bethlehem Shipbuilding Corp.

Designing Welded Frames for Continuity
by BRUCE JOHNSTON and E. H. MOUNT, Lehigh University

Design and Fabrication of Welded Structures
by C. E. LOOS Carnegie Illinois Steel Corp. and F. H. DILL, American Bridge Co.

Present Day Practice in Structural Welding
by A. L. WILSON, Mississippi Valley Structural Steel Co.

Afternoon, 2:00 P.M.—**Committee Meetings; Visit Show**

Evening—**Annual Banquet**—Boulevard Room—Dancing—Price $4.00

Toastmaster—NATHANIEL LEVERONE, President, Automatic Canteen Company of America

Singing by Purdue University Glee Club Don Fernando and his Orchestra

COME TO CHICAGO!!

During the 1939 Annual Meeting of The American Welding Society to be held in conjunction with the National Metal Exposition in Chicago October 23 to 27, there will be presented an outstanding number of papers dealing with resistance welding problems. Users and prospective users of this form of welding owe it to themselves to take advantage of this opportunity to attend these meetings and to discuss their common problems with the leaders of the industry.

The Resistance Welder Manufacturers' Association is proud to co-operate with the American Welding Society in making this year's meeting a great success. We cordially invite you to make the R.W.M.A. booth your exposition headquarters.

COME TO CHICAGO!!

Resistance Welder Manufacturers' Association

505 Arch Street Philadelphia, Pa.

MEMBER COMPANIES

Acme Electric Welder Company, Los Angeles
American Electric Fusion Corporation, Chicago
Eisler Engineering Company, Newark, N. J.
Expert Die & Tool Company, Detroit
Federal Machine and Welder Company, Warren
Multi-Hydromatic Welding and Manufacturing Co., Detroit, Mich.
National Electric Welding Machines Co., Bay City
Progressive Welder Company, Detroit
Swift Electric Welder Company, Detroit
Taylor-Hall Welding Corporation, Worcester
Taylor-Winfield Corporation, Warren
Thomson-Gibb Electric Welding Co., Lynn
Welding Machines Mfg. Company, Detroit

ASSOCIATE MEMBER COMPANIES

P. R. Mallory and Co., Indianapolis
S-M-S Corporation, Detroit
Electroloy, Inc., New York
Welding Sales and Engineering Co., Detroit

FRIDAY, OCTOBER 27th, Morning—9:30 A.M.–11:20 A.M.

SIMULTANEOUS TECHNICAL SESSIONS

North Ballroom

RAILROAD SESSION

Chairman, P. G. LANG, Jr.,
The Baltimore & Ohio R. R. Co.

Vice-Chairman, E. WANAMAKER,
Chicago, Rock Island & Pacific Ry. Co.

Maintenance of Way Welding
by C. E. MORGAN, Chicago, Milwaukee, St. Paul & Pacific R. R.

Automatic Welding in the Design and Construction of Railroad Rolling Stock
by F. C. HASSE, Oxweld Railroad Service Co.

Production Panel Welding of Freight and Passenger Cars
by J. W. SHEFFER, American Car and Foundry Company

South Ballroom

MISCELLANEOUS SESSION

Chairman, K. V. KING
Standard Oil Co.

Vice-Chairman, F. L. PLUMMER,
Consulting Engineer

A Study of Heat Effects in Welding
by Dr. W. A. PEARL, Armour Institute of Technology

Welding in the Manufacture of Valves for High Pressures and Temperatures
by W. F. CRAWFORD and L. H. CARR,
The Edward Valve & Mfg. Co.

Shrinkage of Steel to Correct Distortion from Welding and Forging
by SAMUEL T. SMETTERS, The Sanitary District of Chicago

Adjourn for Business Session at 11:20

North Ballroom

BUSINESS MEETING—11:30 A.M.

Chairman, H. C. BOARDMAN
President, American Welding Society

Annual Report of the President — Election and Installation of New Officers

Presentation of Past-President's Pin

Board of Directors Luncheon Meeting

Afternoon—**Inspection Trip,** Electro-Motive Corporation Plant, La Grange, Ill.

LADIES ENTERTAINMENT PROGRAM

An interesting program for all ladies attending the National Metal Exposition and the meetings of the American Welding Society will be provided. Detailed program will be announced later.

List of New Members

July 1, 1939 to July 31, 1939

CANADA

Blais, Lucien (C), 12A Montcalm, St. Joseph de Sorel, Canada.
Mills, Gordon (D), Ste. B. Karlston Apts. 537 Victor St., Winnipeg, Man., Canada.
Scott, Douglas (D), Waite Amulet Mines, Ltd., Noranda, P. Q., Canada.

CHICAGO

Bassler, Clyde G. (B), Taylor-Winfield Corp., 1225 Washington Blvd., Chicago, Ill.
Carlson, C. E. (C), Chicago Bridge & Iron Co., 1305 W. 105th St., Chicago, Ill.
Menzies, J. C. (C), C. E. Phillips & Co., 332 So. Jefferson St., Chicago, Ill.
Watson, C. O. (B), Taylor-Winfield Corp., 1225 W. Washington Blvd., Chicago, Ill.

CLEVELAND

Lewis, Harry R. (B), The Ohio Seamless Tube Co., Shelby, Ohio.
Mettler, F. W. (B), 999 Rushleigh Rd., Cleveland Heights, Ohio.

COLUMBUS

Roberts, Clay W. (C), 1430 Eastwood Ave., Columbus, Ohio.

DETROIT

Hedrick, Leslie C. (D), 127 Center St., E. Lansing, Mich.

INDIANAPOLIS

Garten, W. R. (C), Sutton-Garten Co., 401–415 W. Vermont St., Indianapolis, Ind.

LOS ANGELES

Cheney, W. B. (C), Southern Calif. Edison Co., Box 351, Los Angeles, Calif.

LOUISIANA

Gust, Louis E. (C), The Linde Air Prods. Co., 828–32 Howard Ave., New Orleans, La.
Leaveau, Victor A. (C), Liberty Welding & Iron Wks., New Orleans, La.
Smith, Paul E. (C), National Cylinder Gas Co., 529 Felicity St., New Orleans, La.
Stockstill, Prentiss G. (D), Freeport Sulphur Co., Port Sulphur, La.

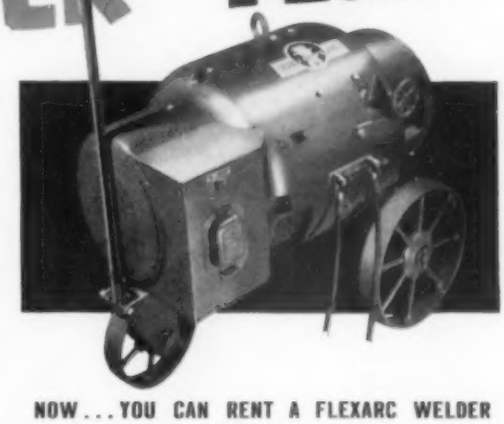
NEW YORK

Dalcher, L. M. (C), 899 Westfield Ave., Elizabeth, N. J.
Lilienthal, F. W. (D), 31–28—91st St., Jackson Heights, Queens, L. I., N. Y.
Perreault, John B. (D), 316 E. 102nd St., New York, N. Y.
Schmuller, Frederick M. (B), Department of Public Works, 125 Worth St., New York, N. Y.

MAKE THE "SHOE-LEATHER" TEST

Welding pays off in feet of work *completed* — not in footwork! That's why the FlexArc Welder with just ONE PRE-SET CONTROL gets more welding done at lower cost. No chasing back and forth to check current — no need for readjustments after the machine warms up. Just set it for the current required and *get* it — for one hour or ten!

Whether your operations involve welding at a distance from the welder or not, FlexArc's simplified control offers savings you should know about before you put money into any welder. Ask for a demonstration and make *your own* test! Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., Dept. 7-N. J-20815



NOW . . . YOU CAN RENT A FLEXARC WELDER

Mail the coupon—get the facts about FlexArc's exclusive features and the FlexArc rental plan. Rental applies against later purchase in full.

Westinghouse Flexarc Welders

LET'S HAVE A SHOWDOWN!

- ☐ Please arrange a FlexArc demonstration
- ☐ I'm interested in full details on FlexArc and the FlexArc rental plan

Name _____

Company _____

Address _____

City _____

Stallone, Leonard (D), 122 Cacciola Place, Westfield, N. J.

NORTHWEST

Bauerfield, Jack E. (D), 268 Lafond St., St. Paul, Minn.

OKLAHOMA CITY

Jenkins, O. O. (B), Jenkins Welding Shop, General Delivery, Jet, Oklahoma.

PITTSBURGH

Timmons, J. J. (B), Fidelity & Casualty Co., 810 Arrott Bldg., Pittsburgh, Pa.

PUGET SOUND

Weinman, Rudolph A. (B), U. S. Bureau of Reclamation, Coulee Dam, Wash.

ST. LOUIS

Schwarting, H. F. (C), 4950 Sutherland Ave., St. Louis, Mo.

SAN FRANCISCO

Sturgess, Robert K. (C), Standard Oil Co. of Calif., 225 Bush St., San Francisco, Calif.

TULSA

Clay, P. L. (D), 416 Industrial, Rt. 1, Sand Springs, Okla.
Nelson, C. S. (D), 1110 No. Detroit, Tulsa, Okla.
Woolman, F. G. (D), Cities Service Oil Co., Ranch Dr., Ponca City, Okla.

WASHINGTON

Eiwen, Chas. J. (C), 3612—12th St., N. E., Washington, D. C.

WICHITA

Moore, Wm. P. (D), 575 Hendryx, Wichita, Kansas.
Schreffler, Chas. L. (D), 1350 So. Market, Wichita, Kansas.

NOT IN SECTIONS

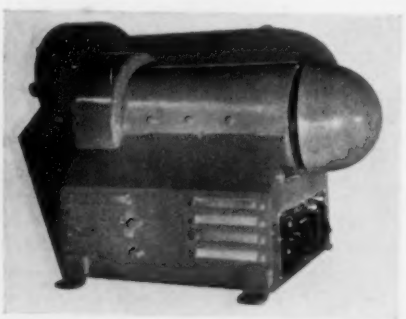
De Maille, Roland (C), Arim, 8, Avenue Gourgaud, Paris, XVII, France.
Lush, Chas. B. (D), Box 244, Earlham, Iowa.
Murray, Stephen W. G. (D), 12 Mousam St., Sanford, Maine.
Smith, W. C. (B), 1503 E. Erwin St., Tyler, Texas.
Wildman, Oliver (D), Carl B. King Drilling Co., Eunice, New Mexico.

NEW PRODUCTS

The Society assumes no responsibility for the validity of claims in this Section

SMALL WELDER

A new small arc welding machine, designed especially for use by garages, blacksmith shops, job welding shops, contractors, machine shops, etc., is announced by The Lincoln Electric Company, Cleveland, Ohio. According to the manufacturer, the new machine makes it possible for such concerns to minimize first costs in equipping for arc welding.



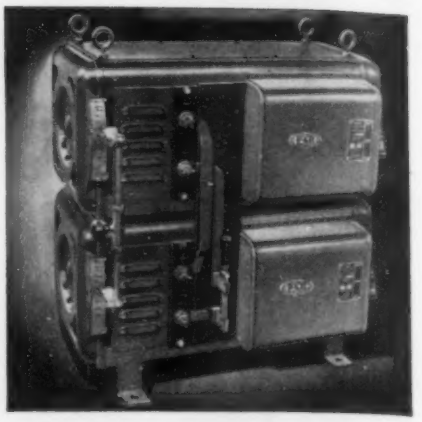
This new welder (see illustration) known as the "Shield-Arc Junior" has been built for use in conjunction with an engine or electric motor drive. Shops which have such equipment available may, therefore, obtain the savings and other advantages which arc welding makes possible. Direct coupled to a gasoline engine or belted to a power take-off from an engine, or connected by belt to line shafting or an electric motor, this welder generates a smooth current for a wide variety of arc-welding applications. Typical profitable uses for this machine include: light-gage metal such as automobile fenders; galvanized sheet; repair of cast-iron parts such as engine blocks; fabrication of angle iron and plate parts and structures; hard facing of plow shares and other wearing parts; and repair of miscellaneous farm implements and machinery. It can be used with either bare or shielded arc type electrodes.

The "Shield-Arc Junior" is rated at 200 amperes and its current range, welding duty, 30-volt arc, is 60 to 250 amperes.

VIBRATION ELIMINATED

When the Harnischfeger Corporation of Milwaukee were developing the new P&H Model WA-200 square frame arc welding service, it was their goal of developing a smaller, more compact machine, more readily adaptable to production line methods of manufacture.

This square frame, extremely rigid welding generator is built with but two main parts: the rugged frame and the rotating member. This type of frame, used for the first time in this modern welding unit, is extremely rigid and designed to protect



bearings against misalignment and wear. Its huskiness is due to heavy members welded into a single unit which cannot "give" and there are no belts or rivets to work loose. This rugged construction, coupled with perfect static and dynamic balance of the rotating member has resulted in elimination of the vibration formerly expected in the ordinary electric arc welder.

So drastic has been this reduction in vibration that during tests in the manufacturer's shop, an ordinary coin was stood on edge and a pencil was balanced on end on the frame while the unit was operating at full capacity.

FLAME-DESCALING

This operator is flame-descaling an 18,000-lb. steel casting for a hydraulic turbine. Flame-descaling is a relatively new process for removing the scale from blooms, billets, slabs, forgings and steel castings by means of specially designed oxyacetylene heating heads. The process is based on the principle that when a high-temperature quick heating is applied to the scale (or oxide skin) on a piece of cold metal, the scale expands and breaks away from the base metal because of differential expansion between the scale and the

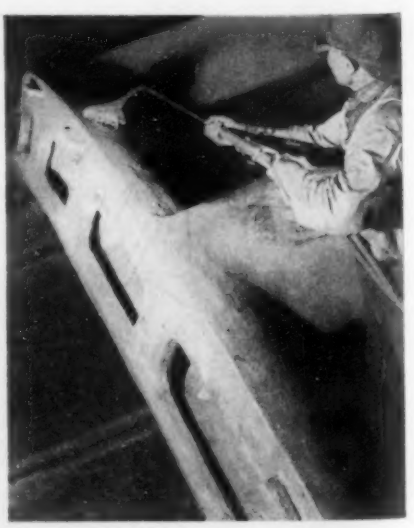
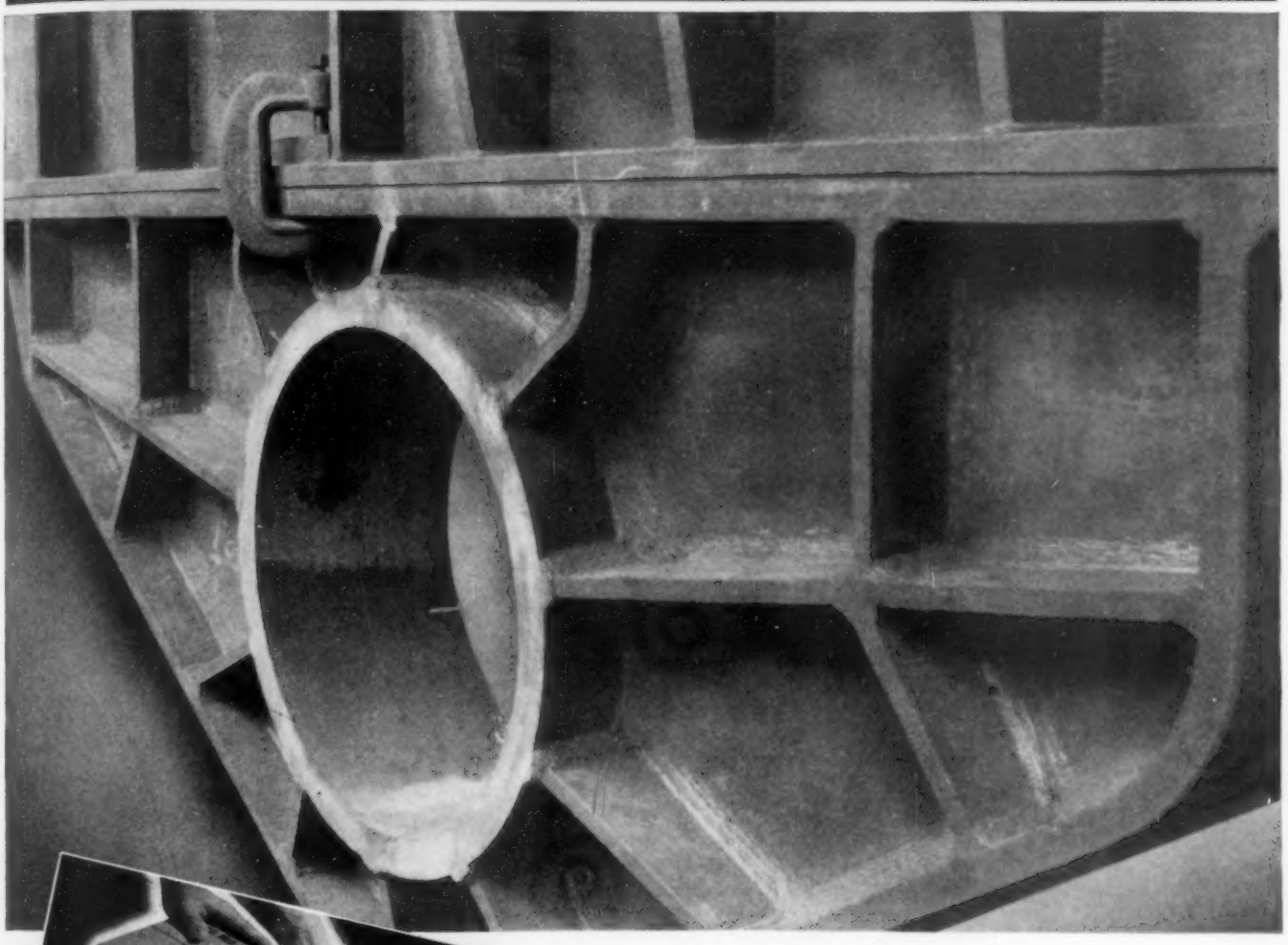


Photo courtesy of The Linde Air Products Co.

No Kicks Thanks to Champion Electrodes



CHAMPION Welding Electrodes are packed in a heavy corrugated cardboard shipping container which is sealed on all sides, and there is imbedded in the cover a wire with a loop to facilitate easy opening. Try CHAMPION Red Devil, Blue Devil, Gray Devil or Black Devil Electrodes—there is a type to meet your exacting requirements. . . . *Send for descriptive folder.*

THIS illustration shows the rear view of what is believed to be the heaviest piece of built up structural steel ever fabricated by electric welding . . . . The design of this structure called for very substantial fillet welds with exceptional physical properties. CHAMPION Electrodes were used throughout with ***complete satisfaction.***

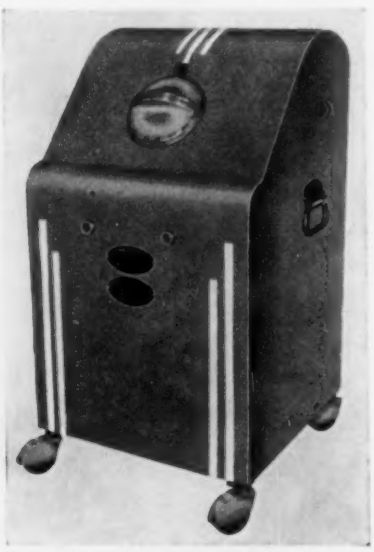
THE CHAMPION RIVET COMPANY

CLEVELAND, OHIO **EAST CHICAGO, INDIANA**

steel. Descaling has a number of advantages over other cleaning methods such as pickling, sandblasting and chipping. The casting shown here, for example, was flame-descaled in one-fifth the time formerly required for chipping.

A. C. WELDER

An entirely new design in A. C. Welders is announced by Miller Electric Mfg. Co., Appleton, Wisconsin. The amperage, voltage and reactance control are all in one dial, placed at an angle and the right height on the front of the cabinet so that the operator can change the dial without stooping to see the amperage markings. He selects the amperage desired, the voltage and reactance change automatically. Illustrated here, is the new welder without welding leads that are easily detachable. The case is of all-steel arc welded so that it cannot break, and designed to furnish perfect ventilation without an open top, so that no metal, dirt, tools or water can fall into the electrical wiring. The finish is durable baked-on enamel. The transformer is designed so that it will not heat surrounding metal parts, and of heavy duty type with air-cooled coils. It holds its rated output regardless of temperature of welder. Built in four models to meet requirements—165, 200, 250 and 300 amperes, each welder comes completely equipped with twenty feet of welding leads, headshield, electrode holder, clamp type ground and assortment of welding electrodes.



IMPROVED AEROPLANE TORCH

For accurate control of the lighter gage metal welding operations encountered in the aeronautical, radio, refrigeration and sheet metal industries, including such operations as saw welding, Victor Equipment Company of San Francisco now offer their new Model J-20 Welding Torch. Instead of the usual nozzle size graduations, the Model J-20 is provided with 13 nozzle sizes covering drill sizes from No. 75 to No. 49. Each nozzle is provided with the patented VICTOR "Spiral Mixer and Gas Proportioner." Thumb valve control permits very accurate flame adjustment while welding.

WELDING ELECTRODES

Four new welding electrodes called Page Surface Saving Electrodes have been added to the line manufactured by the Page Steel and Wire Division of the American Chain & Cable Company, Inc., Monessen, Penna.

These electrodes are alloyed to meet the demand for tough abrasion resisting materials for the original surface maintenance and repair of metal parts subject to excessive wear.

Page Surface Saving Electrodes all inter-alloy with the base metal when applied by the metallic arc method, thus forming a truly welded bond. Four different electrodes are available, each having physical and chemical characteristics suiting them for particular needs.

A comprehensive booklet is available from the manufacturer.

NEW EVENING WELDING COURSE IN NEW YORK CITY

In connection with the new curriculum in Metallurgical Engineering offered by the Polytechnic Institute of Brooklyn beginning this September, Professor Otto H. Henry informs us that a course in Welding and Design has been planned as an added inducement to engineering students interested in construction or metallurgy.

Prof. Henry feels that the steady progress of arc welding, gas welding, brazing, thermit welding and resistance welding processes, the improvements in the use of the oxyacetylene cutting torch for the fabrication of metal shapes and in the application of the oxyacetylene flame to the preparation and heat treatment of metal surfaces have made a thorough knowledge of these processes fully as necessary to the undergraduate as the customary training in pattern making, foundry, metal working, heat treatment and the design of riveted or cast structures.

The course is designed to familiarize the student engineer not only with the more modern methods of construction and heat treatment and the problems involved, but also with the quality of work and economies possible together with the care and inspection necessary to maintain this quality.

The course will treat welding and its several allied processes from the point of view of the engineer interested in the design and fabrication of welded structures or the preparation of flame cut, flame machined or flame hardened shapes.

Emphasis will be placed upon: the types of commercial metals that may be welded, flame cut or heat treated; the various methods of welding, types of joints, methods of flame cutting and heat treating; the physical and metallurgical characteristics of the weld metal or base metal; the economies of welding or allied processes as compared with the older and more familiar processes of fabrication and heat treatment; the types of destructive and non-destructive tests; the preparation and choice of test specimens; physical testing; the interpretation of results; and the problems involved in specifying base metal, welding rods, welding procedure, and in conducting procedure and operator qualification tests prior to the fabrication of equipment together with inspection tests during and after their fabrication.

The lecturer will be Frederick C. Saacki (Apparatus Research & Development Department) of Air Reduction Sales Company. The Course, which will be given in the evening, begins the last week in September and continues three hours a week until February.

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Ask For Them ***Unequaled for Quality***

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And Now, a Modern

ELECTRODE

McKAY SHIELDED ARC WELDING Electrodes

The right electrode and the right method for each job are the keys to successful welding. Every modern resource is employed to improve McKay Electrodes and to aid the user. Ask for folder.

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